CHAPTER I

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Hitherto, research and development activities pertaining to gas sensing devices has gained a rigorous momentum across the world.

"The detection of LPG/CNG gases has become a main issue due to more wellbeing policy wide-reaching."

These sensors can be used for various applications, e.g. monitoring and controlling of the explosive level of concentration of gases, finding of various harmful, dangerous, toxic gases, industrial automation etc. In recent years, the biggest advancement made in the sensor tools is the detection of liquefied petroleum gas and has become tip of the iceberg because outburst accidents force to be happened when it leaks excessively. Therefore, the research work particularly, in the area of wireless sensor network and earlier gas leakage detection (alert system) is imperative.

The monitoring, reorganization and controlling of the data are the key concern of Wireless Sensor Network. The inaccessible interface and actual monitoring with the physical world can be done easily by mote of the network. The wireless sensor networks differ from general data networks, because WSN are application oriented, planned and deployed for dedicated purpose. The wireless sensor network provides extensive range of the applications such as in green monitoring, defense, health, etc [1,2,3].The litheness in plan, enhanced mobility, consistency, broadcast range, reduced power, cost-effective etc are the good features of these network [1,3,4]. Additionally, the system uses the ZigBee technology for wireless communication. This technology is most trustworthy and apposite for interior and outdoor applications. The ZigBee can be configured in star, mesh or peer to peer topology. A demanding subject in scheming WSNs is inadequate power supply for sensor nodes in some application. The breakdown of

a mote results in degradation of the entire network. The preference of a topology can play an imperative role in reduction of power consumption.

The present system is mainly used for the detection of LPG gas. If gas leakage happens at certain place, the present system detects the LPG gas alerts the peoples by buzzering and sending SMS on users mobile phone using arduino GSM shield compatible to the arduino board [5, 6]. The monitoring of the sensor node can be done using G-code created in LabVIEW. The current system provides genuine instance notifications. This system can be installed in a place where LPG is used as a fuel and leakage happens instantly. The present wireless gas detection system plays imperative role model to industry as well as general public.

1.2 The Fundamentals of Sensors

A sensor is a device which converts physical quantity into electrical quantity. The human body which can't sense any quantity can be done easily by commercial sensors like temperature, humidity, intensity etc. Any input signals given to electronic instruments, detection of it and convert them into appropriate output signal, the sensor does it entirely. Nowadays, sensor becomes omnipresent in our regular routines. The properties of sensors are:

- Convert the non-electrical quantity into electrical quantity
- Take action speedily
- Function incessantly
- Portable.

The most significant uniqueness of a sensor is:

- The sensitivity
- The stability associated with it.
- How repeatability it has?

1.2.1 The categorization of sensors

Sensors are categorized according to their conversion property (Fig.1.1). The various sensors according to their properties are classified in physical and chemical category.

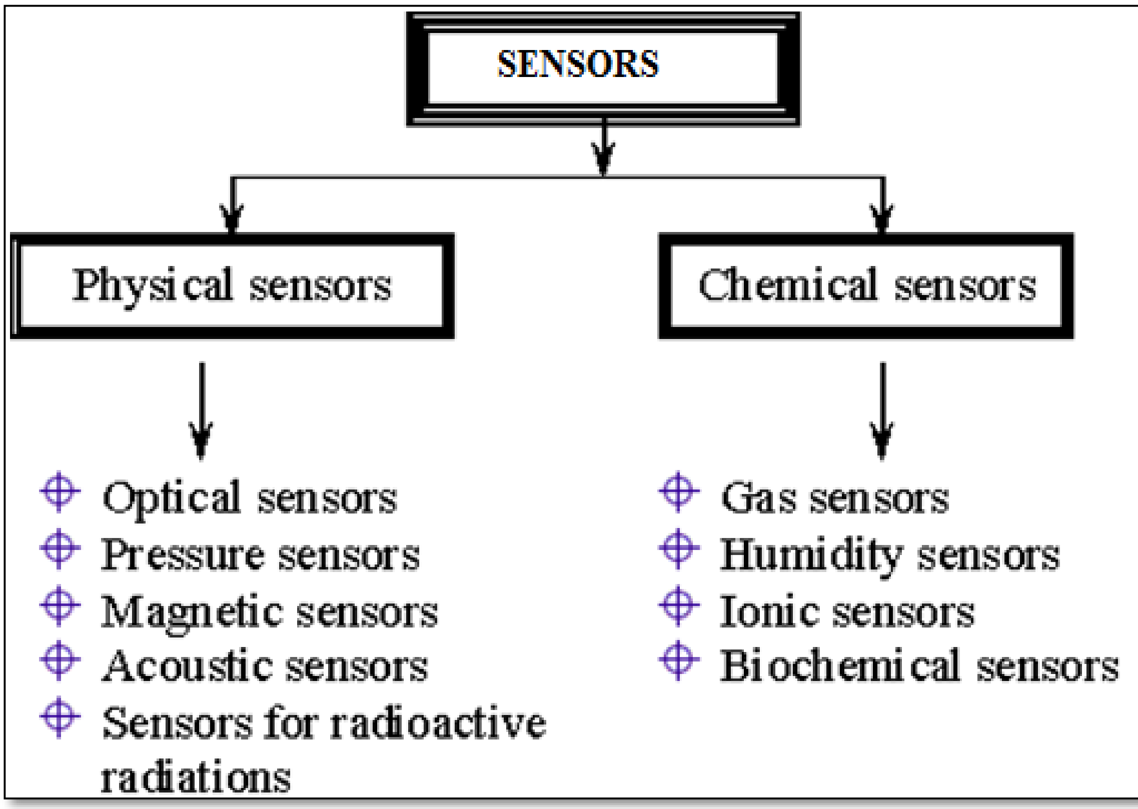

Fig. 1.1. The categorization of sensors.

The different pioneering technology has been used to make the sensor cost effective.

1.2.2 The importance of gas sensors

In the existing scenario, the gas sensors are leading the way from home monitoring to industry monitoring. The gas sensors are indispensable for various applications such as monitoring of various environmental parameters, detection of toxic gases etc. There are different semiconductor gas sensors available in the market having got outstanding position, seeing that they are speedy, consistent,

cost-effective and bare minimum maintenance. Hitherto, ceramic gas sensors were used for detection of gases. The gas sensors are mainly oxidizing and reducing in nature. Whereas oxidizing sensors results in the creation of acceptor states and the reducing sensor results in donor states. The resistive, potentiometric and amperometric sensors [7, 8] are most sensitive sensors.

1.3 The Necessity for Gas Sensors

The olfactory system of humans is outstanding for the recognition of odours which can be observed merely at towering concentrations or can't detect at all [7]. For the protection of human life, to take preventive measure against the explosive concentration of gases and for poisonous gas applications, a gas sensor is essential for the detection of gas in low concentration range. To prevent the gas leakage that happens at homes, industries etc, detection of various gases at low concentration is possible only due to gas sensors. Hence, gas sensor becomes the part and parcel of today's life.

1.4 The Liquefied Petroleum Gas (LPG)

The Liquefied petroleum gas (LPG) has no colour and no smell. The LPG gas liquefies under moderate pressure and vapourize upon discharge of pressure. Therefore, the LPG is stored in liquid form (concentrated). In general, LPG obtained from sanitized crude oil, in this way, it is under pressure form [7] and also from natural gas or crude oil streams. The LPG can be odorized by adding an appropriate odour for the prevention of explosive attacks. The most important property of LPG is that, it is heavier than air. As concentration of LPG increases, it creates hazards to human health [8]. The LPG can be used as a fuel for many sectors, viz. domestic, industrial, cooking processes etc. LPG is also used as a fuel for vehicles [9].

Due to the flammable behaviour of LPG gas, out of harm's way handlings of LPG must be useful in the domestic and industrial situations. Its liquid form is very harmful for the skin [10]. Therefore, to avoid the hazards from this, monitoring and controlling of LPG leakage is carried out through this thesis.

1.5 Literature Survey

To work against the dangerous effects of gas leakage, significant efforts was carried out in manipulative and miniaturizing the gas leak sighting technique. The occurrences of gas leak-related incidents are studied by several researchers and have published statistical data incidents. In 2012, Somov et al [11] reported "Energy-Aware Gas Sensing Using Wireless Sensor Networks" focusing on a sensor node, a relay node, a wireless actuator and a network coordinator. The network coordinator is the main unit of the WSN. It supports the network operation by wireless communication based on the IEEE 802.15.4 standard and the ZigBee specifications. The network coordinator is also responsible for alerting a network operator or an emergency service using the Ethernet network or sending a SMS using a GSM/GPRS modem. In fact, upon receiving the alert message from the sensor node, the network coordinator can perform the first counter action by deactivating the source of gas emission via the wireless actuator [11].

In 2011, Bhattacharjee et al [12] designed a system entitled "Design and Development of a Flexible Reliable Smart Gas Detection System". The system composed of three modules; the base station, wireless sensor array and an intelligent wireless alarm unit, which offers high reliability, flexibility and uninterrupted sensing. These are achieved by incorporating various intelligent protocols like auto sensor calibration, sensor handover, wireless threshold fixation and intelligent alarm mechanism. The sensor node consists of three gas sensors, one temperature sensor and one pyro-electric infrared sensor (PIR) which enhances the sensing intelligence. The sensed data are digitized and processed by the peripheral interface controller (PIC) 16f877A based centralized embedded

platform and wireless communication is achieved with a pair of 433 and 315 MHz amplitude shift keying (ASK) wireless module. The encoding and decoding of sensed data offer a high secured gas detection system [12].

Ya et al [13] pointed out an “Intelligent Residential Security Alarm and Remote Control System Based on Single Chip Computer”. Their work focused on the intelligent residential burglar alarm, emergency alarm, fire alarm, toxic gas leakage remote automatic sound alarm and remote control system, which is based on 89c51 single chip computer. The system can perform an automatic alarm, which calls the police hotline number automatically. It can also be a voice alarm and shows alarm occurred address. This intelligent security system can be used to control the electrical power remotely through telephone [13]. Peijiang and Xuehhua [14] developed a system namely “Design and Implementation of Remote Monitoring System Based on GSM”, which has focused on the wireless monitoring system; a remote monitoring system based on SMS through GSM. The hardware and software architectures of the system are designed. In this system, the remote signal is transmitted through GSM network. The system includes mainly two parts; the monitoring centre and the remote monitoring station. The monitoring centre consists of a computer and a TC35 communication module for GSM. The computer and the TC35 are interfaced by RS232. The remote monitoring station consists of a TC35 communication module for GSM, a MSP430F149 MCU, a display unit, sensors and a data gathering and processing unit. The software for the monitoring center and the remote monitoring station were designed using Visual Basic [14].

A low cost automotive localization system using GPS and GSM-SMS services was proposed by Lita et al [15]. It is concerning “A New Approach of Automatic Localization System Using GPS and GSM/GPRS Transmission”, which provides the position of the vehicle on the driver’s or owner’s mobile phone as a short message (SMS).The system can be interconnected with the car alarm

system that alerts the owner, on his mobile phone, about the events that occurs with his car when it is parked. The system is composed by a GPS receiver, a microcontroller and a GSM phone. In addition, the system can be settled for acquiring and transmitting the information, whenever requested about automobiles status and alerts the user about the vehicle's started engine. The system can be used as a low cost solution for automobiles position localizing as well as in car tracking system applications [15].Investigation on vehicle cabin air quality monitoring system with metal oxide semiconductor gas sensor was the breakthrough in this field by Galatsis et al[16]. Herein, commercially available gas sensors are compared with the fabricated M_0O_3 based sensors. The sensor has a response of 74% or higher relative to the host commercial sensor tested [16]. The same authors have also contributed to the added vehicle safety through a vehicle cabin air quality monitor using carbon monoxide (CO) and oxygen (0_2) gas sensors system designed, developed and on-road tested [17]. The continuous monitoring of oxygen and carbon monoxide provides added vehicle safety as alarm could be set off when dangerous gas concentrations are reached, preventing driver fatigue, drowsiness and exhaust gas suicides. CO concentrations of 30 ppm and oxygen levels lower than 19.5% were experienced whilst driving.

A "GSM Based Gas leakage Detection System" by Srivastava and Prabhukar[18] provides a cost effective and highly accurate system, which not only detects the gas leakage but also alert and turn off the mains power and gas supplies and sends a SMS. Rammaya and Palaniappen [19] reported an "Embedded System for Hazardous Gas Detection and Alerting". The alerting of gas leakage is through buzzer and SMS. A"WSN based Smart System for Detection of LPG and Combustible Gases" has been proposed by Hema et al [20],which identifies potentially hazardous gas leak within an area by means of various sensors based electronic systems. These systems also employ an audible alarm to alert the people whenever a dangerous gas is detected. These gas

detection systems are of immense use because they can be used to detect a wide range of combustible, flammable and toxic gases which have hazardous effects on human health [20]. ”Design Implementation of an Economic Gas Leakage Detector” by Mahalingam et al provided a cost effective audio-visual solution for LPG leakage detection in homes and commercial premises and audibly alert the users in case of a hazardous situation and provide warning signals (beeps) [21].

1.6 An Overview of Wireless Sensor Networks

1.6.1 Wireless sensor network (WSN): a brief history

Wireless sensor networks (WSNs) are paying attention not only in the industry but also in the sector like academia because of their enormous application potential and exclusive safety challenges. The function of this network is to collect the data from the environment and send it to the sink node. Due to the least power and cost-effective application nature, it is more superior to the traditional networks [22-25]. The components of WSN are; sensor nodes, base station and, routers etc. A block sketch of WSN is shown in fig.1.2. It consists of a large number of sensor nodes that collect information from the environment and transmit to the gateway/co-ordinator node. Wireless sensor networks have been used for many applications, from ecological monitoring to logistic, tracking etc. In addition, wireless sensor networks can be used in appliances such as wellbeing monitoring and control, environment and terrestrial monitoring, biomedical health monitoring, home automation, travel control, natural disaster relief and seismic sensing etc,[26, 27, 28]. Fundamental characteristics of the wireless sensor network are small energy consumption, self-motivated network topology, and large scale exploitation. The architecture includes both a hardware platform and an operating system designed.

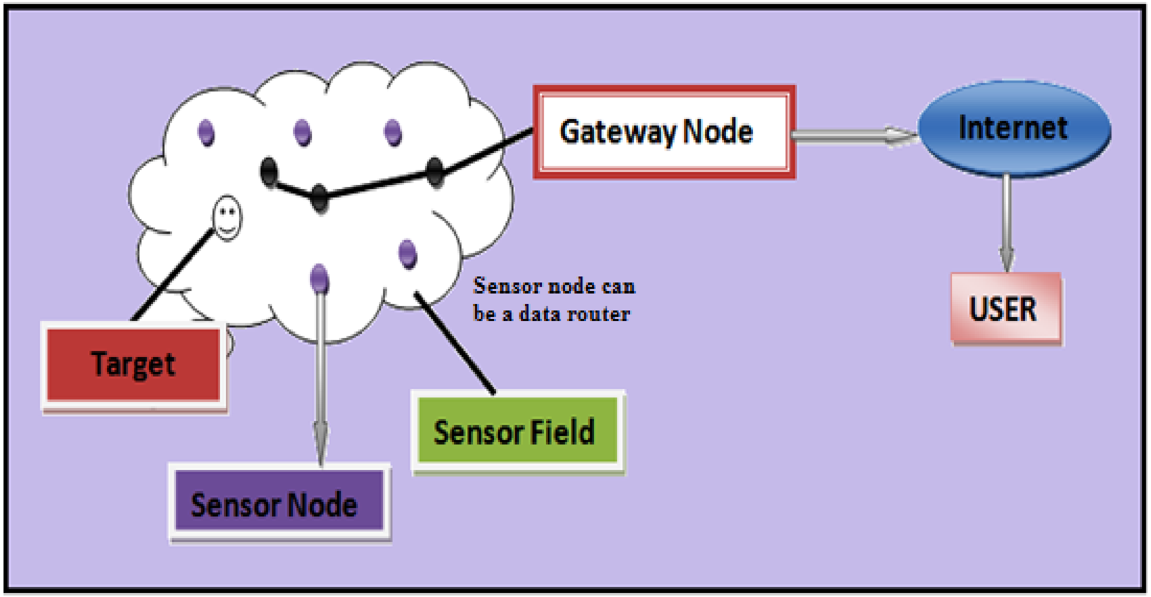

Fig. 1.2. Block diagram of a Wireless Sensor Network.

According to Nack [29], at the Institute of Computer Science, Freie University Berlin, the history of WSN development can be traced back to some projects in Cold-War Era in the United States and can be divided into four stages [29]. For instance, the Sound Surveillance System (also known as SOSUS) was aimed to track Soviet submarines by placing acoustic sensors underwater at key locations as listening posts by US Navy. In the early 1980s, the distributed sensor network (DSN) program was initiated at Defense Advanced Research Projects Agency (DARPA). DSN consists of a set of sensors, which are intelligent and distributed into different areas to obtain and analyze environmental variables from data collected. All the sensors were supposed to operate autonomously and collaborate with each other. Since personal computers and workstations were not popularized and the size of sensors is quite large during that period, the development of many potential DSN projects was limited. However DARPA's efforts, contributions and achievements in DSN drew interests of US military (due to warfare purpose) in the late 1980s. The large replenishment of funds gave the scientists more possibilities to develop sensor network technology. Therefore, WSN technology made a huge and rapid progress in the early 1990s. The latest stage of WSN development lasts

15% till present. With the rapid development of computing, micro-elecrtro mechanical system (MEMS) and other technologies, the sensors are becoming smaller in size and cheaper in price. These advancements provided WSN the opportunities for commercial use in many areas [30]. Companies like Memsic and Crossbow Technology begin to produce wireless motes, sensors and software support. The standardization of protocols also becomes more and more matured. The standards like ZigBee (802.15.4) and 6LoWPAN are built and commonly used in WSN communications.

1.6.2 Why wirelesses sensor networks (WSN)?

The noticeable benefit of wireless transmission is a major reduction and generalization in wiring. The electric wiring cost in industrial installations is 130–650 US$ per meter and using wireless technology, it would be eradicated around 20–80% [31]. The proficient control of the equipment through effectual monitoring of the environment gives rise to extra savings in terms of cost e.g., Wang et al [31]. The wireless system developed by Honeywell to scrutinize steam traps saves the total cost effectively about 100,000–300,000 US$ annually [31]. The impracticable sensor applications, viz. monitoring far-off areas and locations, this technology is featured with unrestricted mechanism and litheness for sensors and augmented the network heftiness. Moreover, WSN technology makes the system reliable and less costly. It allows more rapidly exploitation and deployment of different sensors because this network provides various properties to the sensor nodes. Further, an integration of WSN technology with MEMS makes the motes with enormously stumpy cost, miniatured size and least power. MEMS are the inertial sensors, pressure sensors, temperature sensors, humidity sensors, strain-gage sensors and various piezo and capacitive sensors for proximity. Over the last decade, the technology of Wireless Sensor Network (WSN) has been widely used in many real time applications and these miniaturized sensors can sense, process and communicate. Most wireless sensor nodes are capable of measuring

temperature, acceleration, light, illumination, humidity; level of gases and chemical materials in the surrounding environment.WSN is a compilation of wireless sensor nodes. A WSN is also an amalgamation of an integer of motes with limited communication ability. The co-ordination between the sensor nodes provides ability to process and to gather information in a large amount [32, 33]. Also, ad-hoc networks can be created. Generally, WSN networks are categorized in two types: structured and unstructured. In unstructured WSN, the sensor nodes are deployed in an ad-hoc manner without any careful planning. Once nodes are deployed, monitoring and processing of data is done in unattended environment. In structured WSN, motes are deployed in pre planned approach. The structured wireless sensor network is superior to unstructured one, because cost and maintenance required to deploy the node are less. The nodes in structured WSN are positioned at exact locations to offer coverage, whereas unstructured deployment has uncovered areas. Wireless sensor network aims to give co-ordination among the physical conditions and the internet globe. It has the following features:

- WSN should be reliable
- More accurate
- Flexible in nature
- Cost effective
- Easy to install.

Tilak et al [34] have shown that the intellectual sensors can gather data from disaster area, floods and also from revolutionary attacks. The network is promising for,

- Collection of information
- Dealing out of information easily and

- Environment monitoring for numerous applications.

Due to the above advantages WSN becomes an integral part of near future applications. Today's devices are used basically in underground and underwater applications and also on land. We have therefore various challenges and difficulties depending on the environment situations. These networks are of five types depending upon their functions and structures e.g. multi-media, mobile, land, underground and underwater WSNs [35]. Global WSNs involves use of 100 to 1000 of sensor nodes assembled either in an ad-hoc or in a pre-determined manner. The sensor node in global WSN is relatively inexpensive, for it does not need to fulfill the resistance to stress as in underground WSNs or the water proofness as in underwater. We pre-planned the deployment of global (terrestrial) WSN for our work.

Gas leakage can happen anywhere and at any time; hence wired sensors could not be implemented in remote areas. Also it is very complex and costly to mount and sustain the wired networks. Additionally, if a wire between the two nodes gets breaks, the communication between these two nodes gets collapsed; hence, the entire network will also fails. The WSN with a star topology is prefer here because the sensor nodes are strongly cluster together and they communicate only with single co-ordinator node. This property helps the individual sensor nodes to save the battery power. Hence, star topology helps to reduced power consumption among the sensor nodes. The data composed from WSNs are massive in a real life situation and so, mining of this data is most important. Our aim is to design, develop and discuss a wireless gas sensing system; an application that would be developed and tested in order to detect the hazardous gas leakage detection using WSNs.

1.6.3 Wireless sensor nodes

A wireless sensor network is miniaturized and compact in behaviour. Mostly, it provides thousands of insignificant devices, called as sensor nodes and

are integrated to collect the information from various resources. The nodes are of different sizes and takes disadvantage of varying size and cost to pose different constraints. The motes are developed using four components (fig.1.3), i.e 1. processing components made up of processor or controller, 2. radio components for providing wireless communication between nodes, 3. device to convert data from environment into electrical quantity and 4.batteries to provide power supply to the network [36]. Each component plays a most important role in the working of motes. Radio subsystem allows the sensor node to interact with the exterior world. It uses various techniques such as Bluetooth, ZigBee; UWB operates at ISM band frequency of 2.4 GHz. Microprocessor or microcontroller subsystem is used to provide logical decision power to the sensor nodes. It commands the actuators and developed necessary algorithm for network performance. To preserve an energy, microprocessor works in off, sleep, idle and active modes according to the status of the sensor nodes.

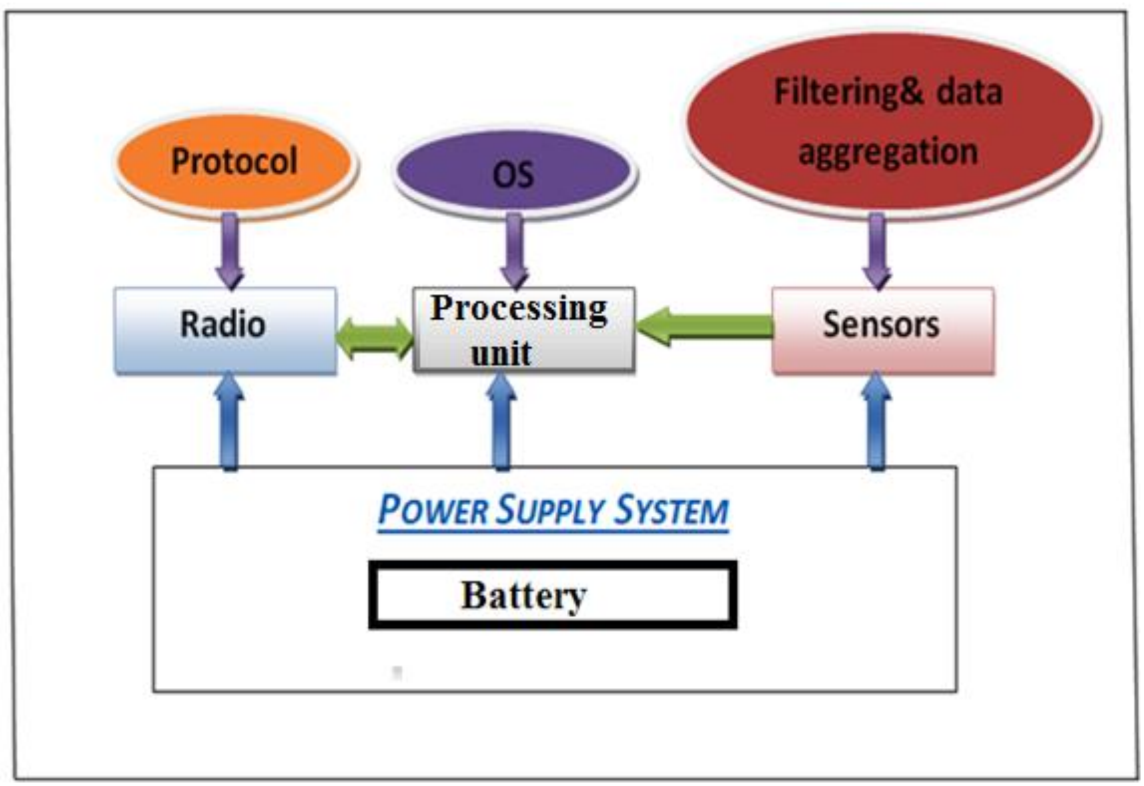

Fig.1.3. Sensor node architecture.

Sensor is used according to the application of the sensor nodes for which network has been deployed. The battery plays an important role to improve the lifetime of the network. Therefore, lifetime of motes thoroughly depends on the battery and network's lifetime on the sensor nodes [37, 38, 39]. Depending on the environment, backup power supply is added. Solar battery is a best choice.

1.6.4 Issues in wireless sensor networks

Wireless sensor networks (WSNs) are composed of numerous small, low-cost, randomly located nodes. The network can be scalable to thousands of nodes that cooperatively perform complex tasks such as intelligent measurements. The network must be able to self-organize, adapt to random node spacing, execute algorithms for signal processing and operate as power efficiently as possible .A WSN has its own design and resource constraints due to the limited size and cost of sensor nodes such as limited energy and storage, short communication range, low bandwidth and limited processing, which are different from the traditional sensor networks. Ad-hoc and sensor networks share a number of challenges such as energy constraints and routing [40]. On the other hand, general ad-hoc networks most likely induce traffic patterns different from the sensor networks, have other lifetime requirements and are often considered to consist of mobile nodes [41, 42]. In WSNs, most nodes are static; however, the network of basic sensor nodes may be overlaid by more powerful mobile sensors (robots) that, guided by the basic sensors, can move to interesting areas or even track intruders in the case of military applications. Recent technology in wireless communication and electronics have overcome some of the constraints and enabled the four developments of sensor nodes which are low-power, low-cost, multifunctional and small in size. However, three primary problems such as energy efficiency, localization and routing still hold.

a) Energy efficiency

The power unit supports all the activities on sensor node, including communication, local data processing, sensing, etc. The lifetime of a sensor node is mainly determined by the power supply since battery replacement is not an option in sensor networks, especially in dangerous environments such as in battlefields or environment monitoring. As a result, every aspect of the wireless sensor networks, from mote location through computing and communication is viewed from the low-power perspective. Lifetime is extremely critical for most applications and its primary limiting factor is the energy consumption of the nodes, which needs to be self-powered. The longer the lifetime of a sensor, the more stable the WSN. In order to save power, redundant activities should be reduced if not eliminated. The most important factor to determine the life of a sensor network is the energy consumption. Driven by a battery which is limited in power and may not be rechargeable, sensor node is facing the big challenge of conserving energy. Each mote depends on a low-capacity battery's as an energy source. Practically, the chance for battery replacement is nonexistent and sensor nodes are deployed in unattended environment where battery replacement is not possible. Hence, energy consumption is a vital factor to prolong sensor nodes lifetime. If energy awareness can be applied in every stage of the wireless sensor, the lifetime of the wireless sensor network can be maximized. Moreover, it will be more powerful for wireless sensor networks to have the ability to make tradeoffs between energy consumption and system performance.

To improve the energy efficiency for a static sensor network, different techniques are available such as clustering [43-46], use of broadcast and multicast trees [47-49] and exploitation of sleep modes[50, 51].It is imperative to prevent sensor nodes from wasting energy in receiving packets unintended for them. Combined with efficient medium access protocols, the "sleeping" approach could reach optimal energy efficiency without degradation in throughput.

b) Localization

To have a faithful data to the users, sensor nodes must be used randomly in the particular area, so that they must be aware of their locations to provide the data. Hence the most fundamental and complex problem in WSN is the place where network is to be established [52]. This location is dependent on many factors and requirements potentially making it very troublesome [53]. e.g., cost of extra localization hardware, beacons with their number and ranges, and their degree of location accuracy, whether the system is indoors/outdoors, line of sight umong the nodes, whether system is 2D or 3D , energy budget and duration of localization, whether clock synchronized and kind of errors being made and security attacks etc. In some cases difficulties are easily encountered. If the cost and form factor are not of prime importance and few meters accuracy is considered, then equipping of GPS is a probable answer. Majority of the localization solutions in WSN are either range dependent or range- free. Range-dependant schemes involve determination of distances between nodes (range) and then location can be determined geometrically, whereas in range-free schemes, but hop counts are used (distances are not determined directly). When hop counts are estimated, distance between the nodes can be calculated geometrically to know the location [54]. Various localization techniques can be classified as fine-grained and coarse-grained. Timing, strength of the signal and pattern match and directionality are the characteristics of the fine-grained localization, whereas coarse-grained is based on multilateration and recursive trilateration.

The following are the rules for the localization:

- ✓ System should work in the absence of node working
- ✓ Immune to the noise
- ✓ Estimated error should be low
- ✓ Suitable for any territory.

c) Routing

For WSN, routing is important as far as power consumption is considered. The network lifetime enhancement is a function of various power reducing factors. The energy harvesting system has a major role instead of the data quality sent by the motes to improve the network lifetime performance. Hence, conservation of energy is also important compared to the performance of the network.

The literature survey shows the design principles for router that have been extensively studied. Data compression with routing enhances the scalability of the network [55]. There are three types of routing in WSN: flat-based routing, hierarchical- routing and adaptive routing. In first, all nodes are assigned equal roles [56] whereas in second, nodes have various roles in the network [57]. In the third routing system parameters are controlled to adapt current conditions. [58, 59]. SPIN (Sensor Protocols for Information via Negotiation) and Directed Diffusion are two primary routing protocols in wireless sensor networks. SPIN protocols use information description for negotiation among all the sensor nodes before transmission of the data [60]. Reactive routing sends out a sensing task that it needs throughout the network and then the data node, sends it back to the former [61]. Reference [62] discusses a variety of energy aware routing protocols.

1.6.5 Applications

WSN is used in applications like security, monitoring, biomedical research, tracking etc [63, 64, 65]. The reduction in cost of the sensor nodes and energy may lead revolution as far as applications of WSN are considered. The following figures depict application potential of WSNs.

a) Environmental monitoring

The wireless sensor networks (WSN) is the most momentous technologies in today’s world. Fig.1.4 shows advancements and use of WSN in ecology monitoring.

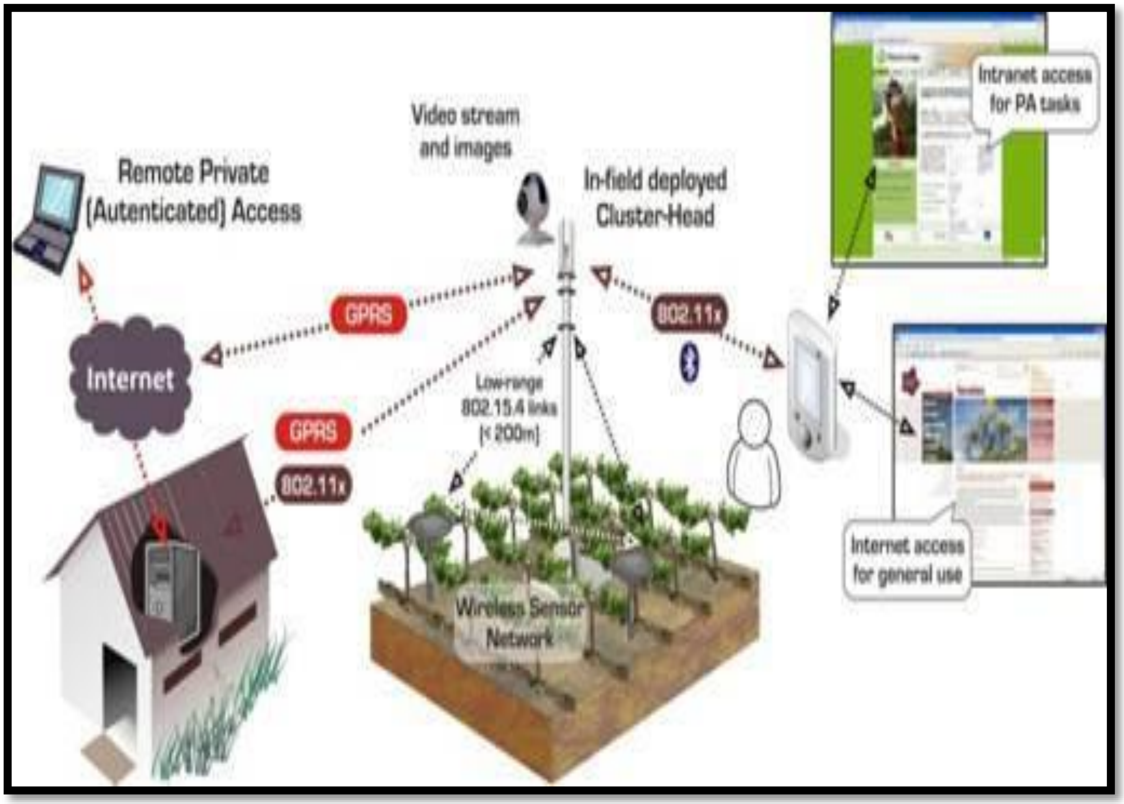

Fig.1.4. Environmental monitoring using WSN.

The monitoring of numerous parameters occurs in environment as humidity, salinity, blustery weather direction; airstream is done greatly using WSN, also data can be sent on web browser for remote interaction [66]. After employing the WSN in the green monitoring, one can overcome the traditional data logger system.

b) Home automation

Home automation and its smart intelligence, automatic monitoring and controlling of housing parameters through effective use of WSN technology makes it ingenuous. Using WSN, activities pertaining to the household application can be done automated without any human intrusion [67].The home automation using WSN such automatic windows and door opening system, to turn off the lights in our rooms, corridor, etc. All these happen automated, which saves electricity consumption, makes our homes smart. Fig.1.5 depicts the diagram for home automation using WSN.

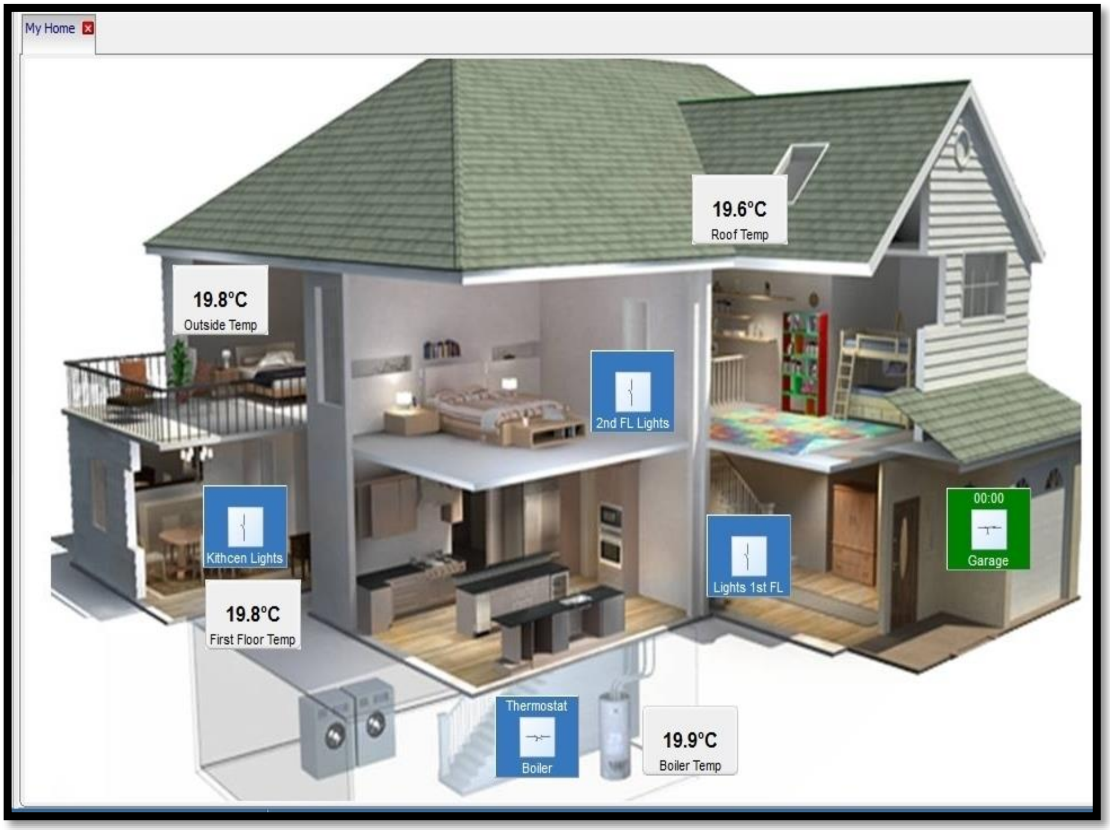

Fig.1.5. Home automation using WSN.

c) Health monitoring

The health care area uses WSN system more effectively (fig.1.6). In hospitals, sensor networks are used to check physiological data of patients, to provide drug diagnosis and monitor patients and doctors inside a hospital [68]. The medicinal applications are of two types: wearable and implanted. Wearable devices are used on the surface of a human body or at close proximity of the user. The implantable devices are inserted inside the human body. WSN performs various health care applications such as patient diagnosis at homes or hospitals, measurement of location of patient body etc. Additionally, an application of body area networks involves collection of information about an individual's health, fitness etc.

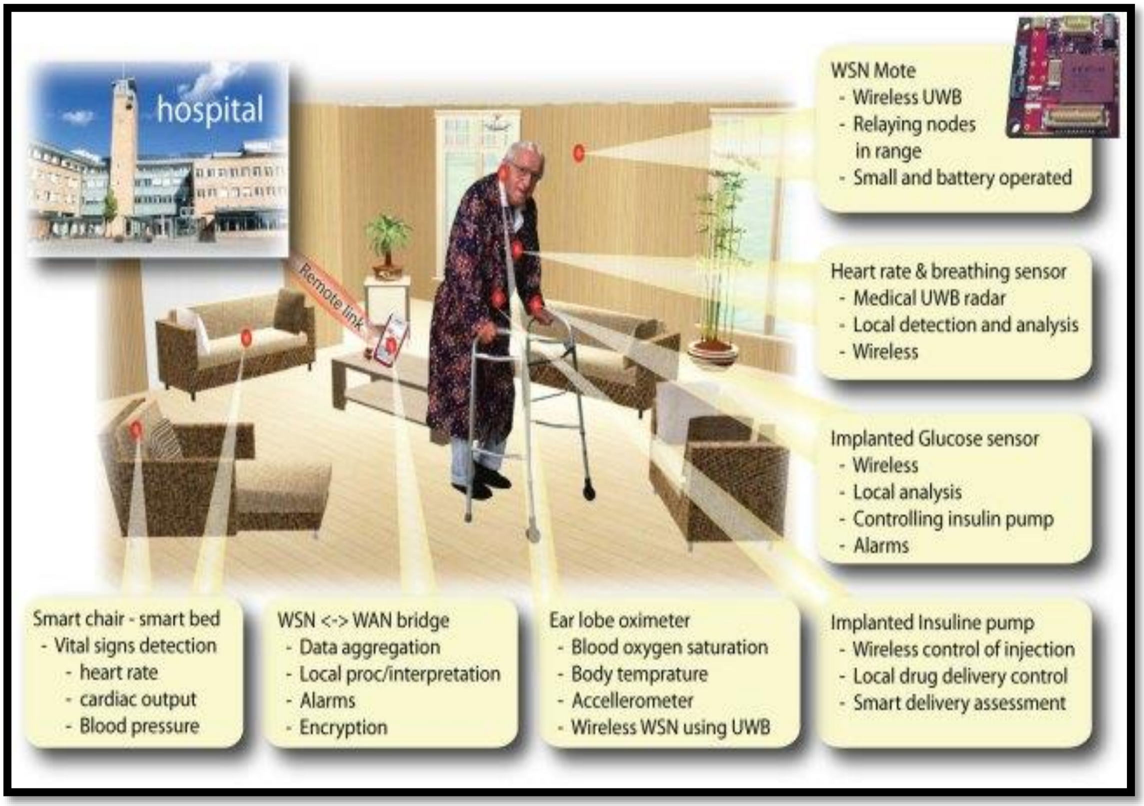

Fig.1.6. Health monitoring using WSN.

d) Air pollution monitoring

To avoid health hazards, the wireless sensor networks based air pollution monitoring system is used to monitor the concentration of pollutant, toxic, combustible gases (fig.1.7). Instead of using wired data loggers system, it uses ad-hoc deployment for monitoring the gases in diverse areas.Wireless Sensor Network is the most outstanding technology used to collects the information from environment, process it and send it to the user directly [69]. These networks permit the calculation of the physical data at high resolutions and increase the superiority and extent of real data o a great extent along with information for applications like toxic waste monitoring, pollution monitoring etc.

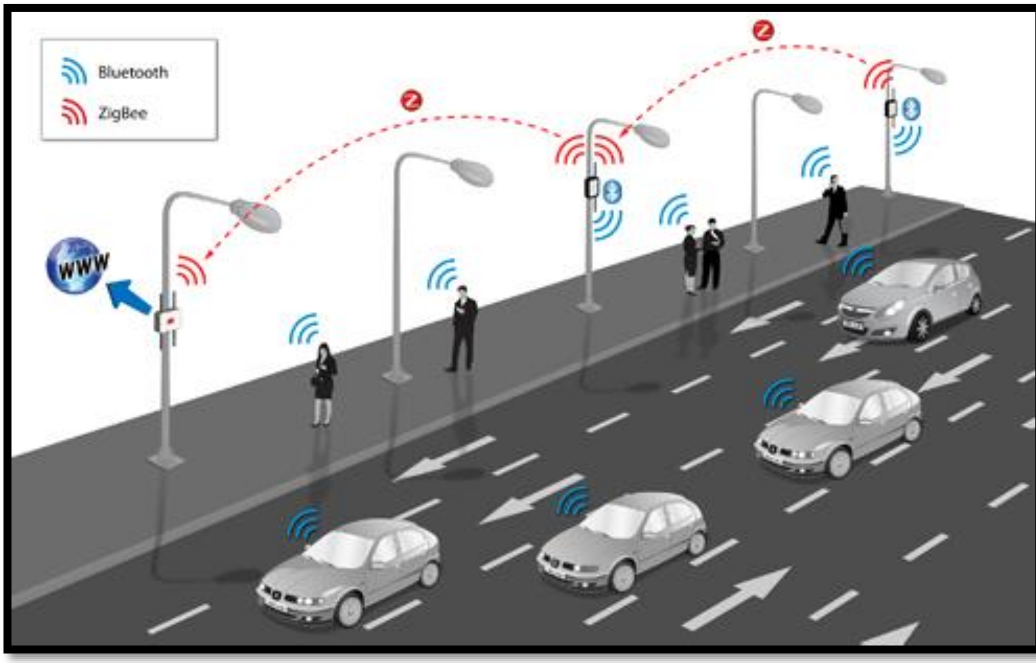

Fig.1.7. Air pollution monitoring using WSN.

e) Forest fire detection system

The forest fire detection (fig.1.18) is used to detected a fire has initiated within forest area.

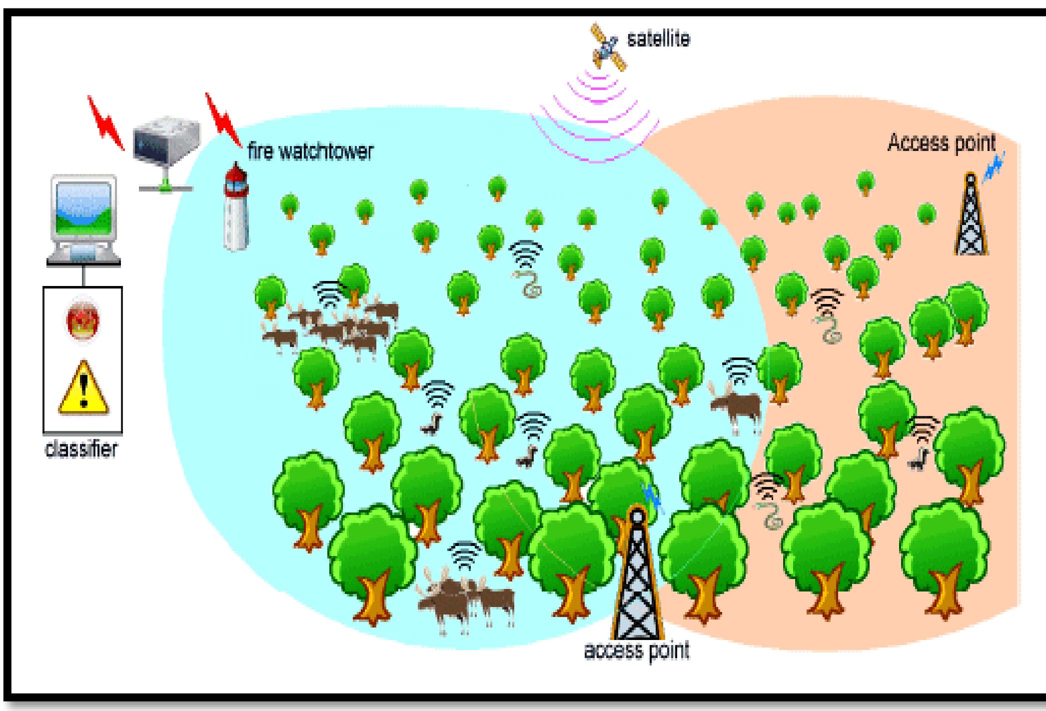

Fig. 1.8. Forest fire detection.

The nodes with different sensors are used to measure various environmental affects produced by the fire in the jungle [70]. Using wireless sensor networks the status of the fire can be easily detected and informed to the fire brigade. This is the biggest achievement using WSN technology.

f) Earthquake and landslide detection using WSN

Using WSN the natural disaster like earthquake will be detected before they occur. Also, the happening of landslides before it occurs will be detected using this system [71].

g) Smart agriculture system

For smart agriculture system the competent water administration must be required. The monitoring of crop fields, scheduling of water and crop growth are the key apprehension of precision agriculture system, enhanced using emerging and inventive technology i.e. WSN. The blessings to agriculture sector using WSN is shown in fig.1.19. The production loss due to unirrigated areas can be improved using this technology [72].

h) Military application

Wireless sensor networks must be an integral part of military command controls, communications, computing, intelligence, surveillance, reconnaissance and targeting systems (fig.1.10). In the battlefield context, rapid deployment, self-organization and fault tolerance security of the network should be required [73]. The sensor devices or nodes should provide: like monitoring friendly forces, equipment and ammunition, battlefield surveillance, reconnaissance of opposing forces, targeting, battle damage assessment and nuclear, biological and chemical attack detection reconnaissance, etc.

Fig.1.9. WSN: Blessings to agriculture sector.

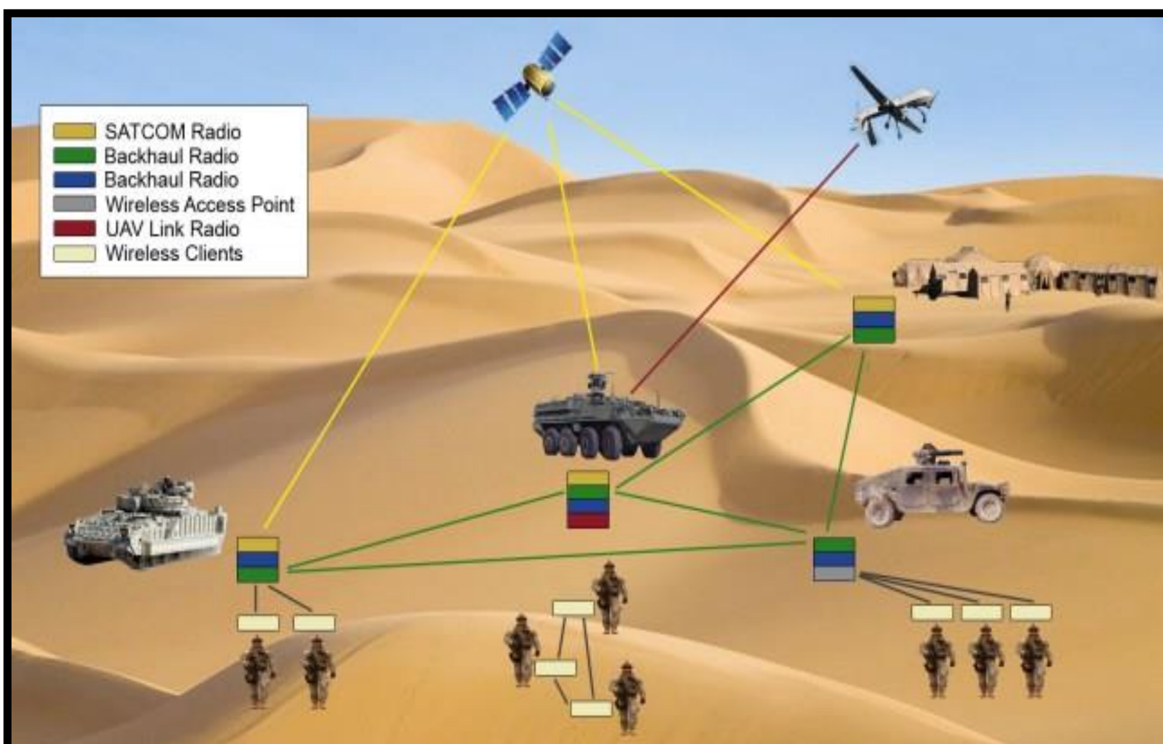

Fig.1.10. Military applications using WSN.

1.7 The IEEE 802.15.4 and ZigBee Standard

1.7.1 An overview

This provides a brief description of some of the important features of the IEEE 802.15.4 and ZigBee protocols. There are a multitude of proprietary wireless systems manufactured today to solve a multitude of problems that also don't require high data rates but do require low cost and very low current drain. These proprietary systems were designed because there were no standards that met their requirements. These legacy systems are creating significant interoperability problems with each other and with newer technologies. The ZigBee alliance is not pushing a technology; rather it is providing a standardized base set of solutions for sensor and control systems. ZigBee is poised to become the global control/sensor network standard. It has been designed to provide the following features:

- Low power consumption.
- Bluetooth has many different modes and states depending upon your latency and power requirements such as sniff, park, hold, active, etc. ZigBee/IEEE 802.15.4 has active (transmit/receive) or sleep modes. Application software needs to focus on the application, not on which power mode is optimum for each aspect of operation.
- ZigBee devices will be more ecological than its predecessors saving megawatts at it full deployment.
- Low cost of device its installation and maintenance. It requires low cost primary battery cells, do not require battery charging and simplicity allows for inherent configuration and redundancy of network devices providing low maintenance.
- High density of nodes per network
    - ✓ ZigBee's IEEE 802.15.4 PHY and MAC allow networks to handle any number of devices. This attribute is critical for massive sensor arrays and control networks.

- Simple protocol, global implementation
    - ✓ ZigBee's protocol code stack is estimated to be about 1/4th of Bluetooth's or 802.11's. Simplicity is essential to cost, interoperability and maintenance. It is a protocol that uses 802.15.4 standard as a baseline and adds additional routing and networking functionality [74-75]. The IEEE 802.15.4 PHY has been designed for 868 MHz band in Europe, the 915 MHz band in N. America, Australia, etc. The 2.4 GHz band is now recognized to be a global band accepted in almost all the countries.

1.7.2 The architecture of ZigBee

The two most common RF radios that are available from Digi are the Series 1 and Series 2 XBee. The Series 1 and Series 2 modules are quite similar, but selection of a module should be based upon application specific needs.

All XBee radios have the same footprint and for the most part, are pin to pin compatible (with a few differences in the placement of ADC/IO lines), but are not interoperable. Series 1 and Series 2 use different application profiles, which are unique to each radio family. They can however, use the same RS232 or USB interface boards. The ZigBee devices are classified into two according to their architecture as;

1. ZigBee Series-1: These radios use a microchip made by freescale that provides a simple and point to point communication.
2. ZigBee Series-2:- It uses a microchip from Ember networks that enables several different flavours of standards.

   Both the series 1 and series 2 ZigBee devices are available in two different versions such as regular and PRO [76]. The regular version is simply called an XBee and other is XBee-PRO, which has more power consumption and relatively more expensive. The ZigBee devices are shown in fig. 1.11.

Fig.1.11. Top and bottom views of XBee.

This XBee module has S2 hardware. The top side got only the antenna chip, which replaces the regular antenna. In the left side, there is a place for a little antenna when the antenna chip is not used. The ZigBee devices use different types of antennas. Two of the most popular version are the chip antenna and whip antenna. These use a chip with the actual antenna structure embedded in the chip. Many of these devices use a whip (external) antenna via connector.

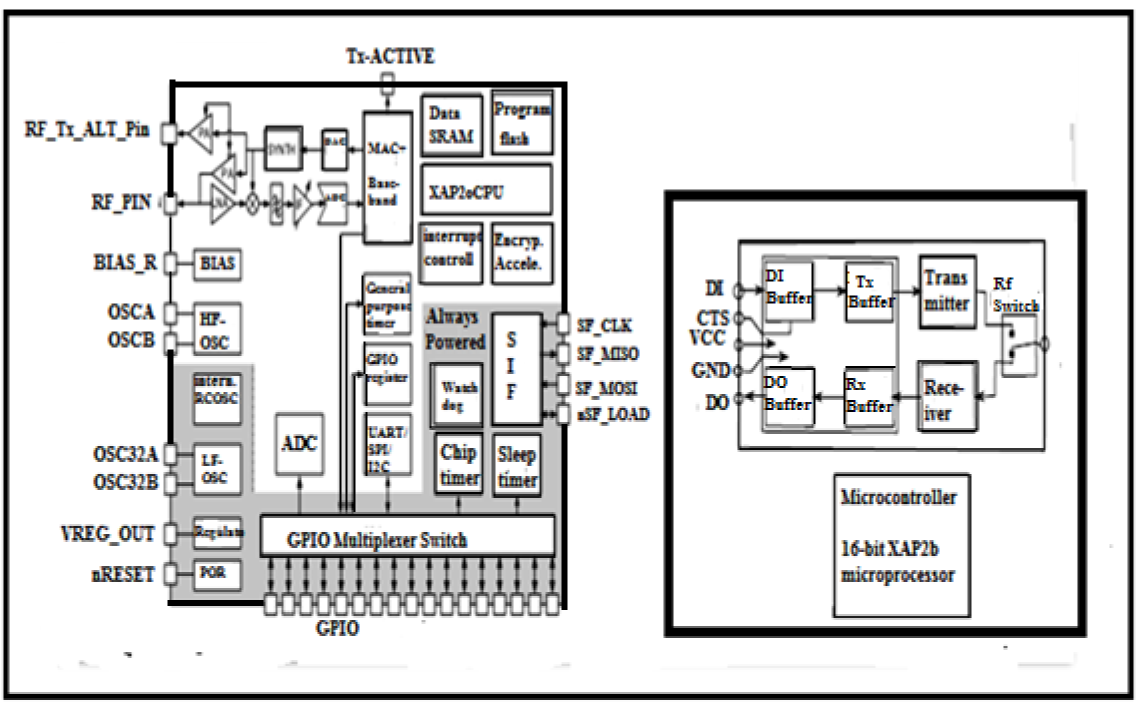

Fig.1.12. XBee internal block diagram.

Generally, the XBee module consists of the following internal parts as the block diagrams describe (fig.1.12). It consists of a 16-bit microcontroller with all parts that any 16 – bit microcontroller could have (ADC, Timer, Watchdog, Sleep timer, UART, General-purpose I/O port, 128kB of Flash , 5kB of SRAM …etc.). Beside the microcontroller, some other parts are for communication. The microcontroller designed by Cambridge Consultants Ltd and runs on a 12 MHz clock speed. A hardware AES encryption engine is included also in the EM250.

1.7.3 The features of ZigBee

The salient features of both the ZigBee devices are cited as follows. On investigation of the structural details, it is found that ZigBee module of series 2(S2) is most suitable for establishment of the WSN.

	XBee Series 1	XBee Series 2
Indoor/Urban range	up to 100 ft. (30m)	up to 133 ft. (40m)
Outdoor RF line-of-sight range	up to 300 ft. (100m)	up to 400 ft. (120m)
Transmit Power Output	1 mW (0dbm)	2 mW (+3dbm)
RF Data Rate	250 Kbps	250 Kbps
Receiver Sensitivity	-92dbm (1% PER)	-98dbm (1% PER)
Supply Voltage	2.8 - 3.4 V	2.8 - 3.6 V
Transmit Current (typical)	45 mA (@ 3.3 V)	40 mA (@ 3.3 V)
Idle/Receive Current (typical)	50 mA (@ 3.3 V)	40 mA (@ 3.3 V)
Power-down Current	10 uA	1 uA
Frequency Dimensions	ISM 2.4 GHz 0.0960" x 1.087"	ISM 2.4 GHz 0.0960" x 1.087"
Operating Temperature	-40 to 85 C	-40 to 85 C
Antenna Options	PCB, Integrated Whip, U.FL, RPSMA	PCB, Integrated Whip, U.FL, RPSMA
Network Topologies	Point to point, Star, Mesh (with DigiMesh firmware)	Point to point, Star, Mesh
Number of Channels	16 Direct Sequence Channels	16 Direct Sequence Channels
Filtration Options	PAN ID, Channel & Source/Destination	PAN ID, Channel & Source/Destination

The pin diagram of XBee is shown in fig.1.13.

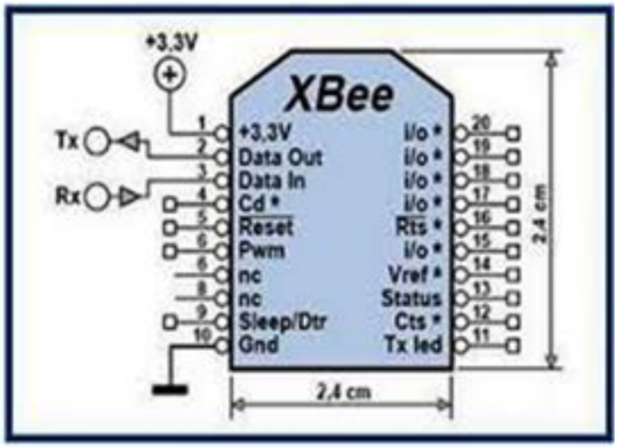

Fig.1.13.Pin diagram of XBee.

The following table shows the pin description of the XBee.

Pin	Name	Direction	Default state
1.	VCC	Output	Output
2.	DOUT	Input	Input
3.	DIN/$\overline{\text{Config}}$	Both	Disabled
4.	DIO12	Both	Open-collector with pull-up
5.	$\overline{\text{RESET}}$	Both	Output
6.	RSSI PWM/DIO10	Both	Input
7.	DIO11	Both	Disabled
8.	[reserved]	Both	Input
9.	$\overline{\text{DTR}}$/SLEEP_RO/DIO8	Both	Input
10.	GND	Both	-
11.	DIO4	Both	Disabled
12.	$\overline{\text{CTS}}$/DIO7	Both	Output
13.	ON/$\overline{\text{SLEEP}}$	Output	Output
14.	VREF	Input	-
15.	Associates/DIO5	Both	Output
16.	$\overline{\text{RTS}}$/DIO6	Both	Input
17.	AD3/DIO3	Both	Disabled
18.	AD2/DIO2	Both	Disabled
19.	AD1/DIO1	Both	Disabled
20.	AD0/DIO0/Commissioning Button	Both	Disabled

1.7.4 The ZigBee topologies

The ZigBee networks use different network topologies, e.g. peer-to-peer, star and mesh (fig.1.14).

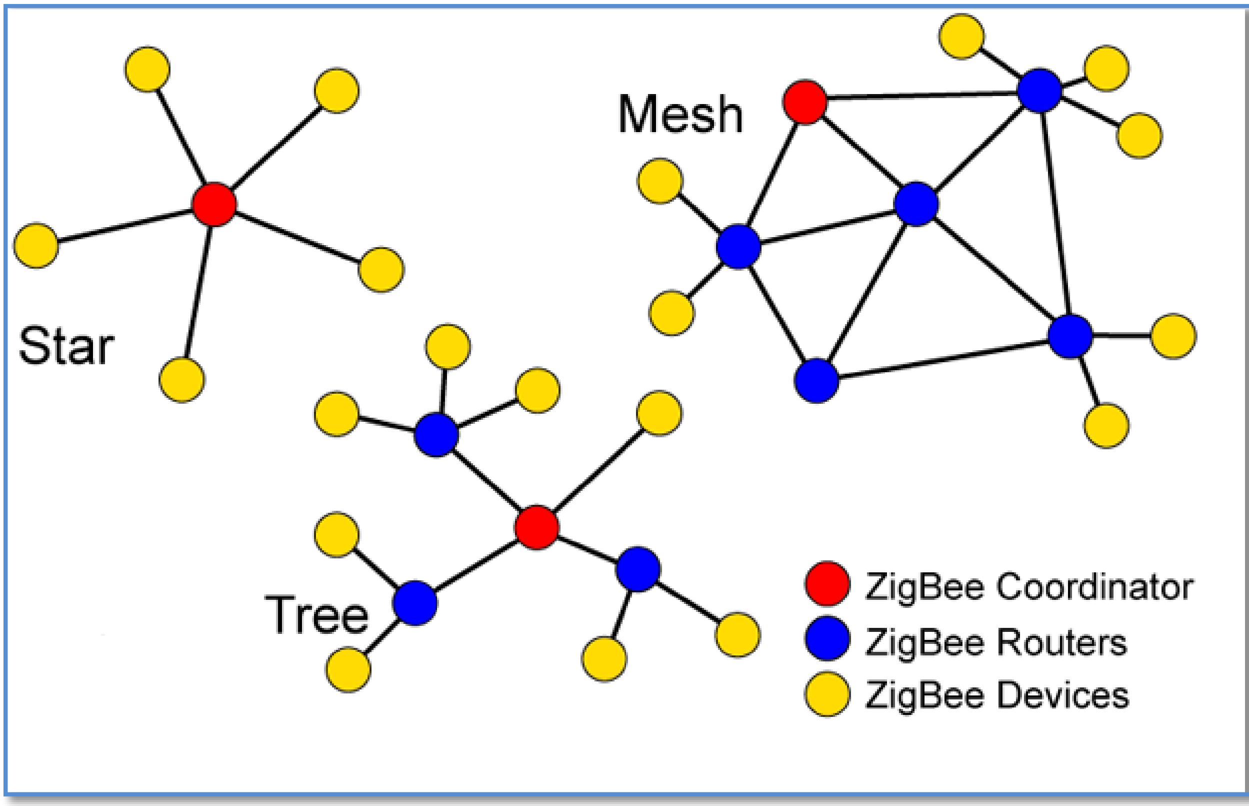

Fig. 1.14.The various topologies of XBee.

a) Peer to Peer topology

In peer-to-peer topology ZigBee network nodes help other devices directly to connect to each other [77].One node of ZigBee network device keeps the ability to form a network by connecting multiple devices. In peer-to-peer networking topology, one ZigBee network device node is connected to other node for network formation. It forms a grid like structure. ZigBee networks have short range wireless networking and form a simple network, without any complexity.

b) Star topology

Star topology of ZigBee [78] network makes all the devices attached to a central control unit. Multiple routers may also be used to increase the ZigBee network range. The complexity of this module makes it difficult to tell that which

node is connected to which one but in case of any breakdown the ZigBee network finds an alternate route to execute the command sending through coordinator and does not get affected itself.

c) Mesh topology

Mesh topology (also called peer-to-peer) consists of a mesh of interconnected routers and the end devices. Each router is typically connected through at least two pathways, and can relay messages for its neighbours. Mesh topology supports "multi-hop" communications through which data is transmitted by hopping from device to device using the most reliable communication links and most cost-effective path until its destination is reached [79]. The multi-hop ability also helps to provide fault tolerance, in that if one device fails or experiences interference, the network can reroute itself using the remaining devices. A mesh topology is self-healing, means during transmission, if a path fails, the node will find an alternate path to the destination. Devices can be close to each other so that they use less power.

1.7.5 The ZigBee network devices

ZigBee networks include the device types as; coordinators, routers, end devices (fig.1.15)

.

a) Coordinator

The coordinator stores information about the network, which includes acting as the Trust Center being the repository for security keys. For performance of the network the co-ordinator node need to be installed firstly, having same PAN ID with respect to router or end devices. The PAN ID and channel selection is done through sink node. [80]. The controlling of the network is done through it. The coordinator is configured as the conviction center and network supervisor.

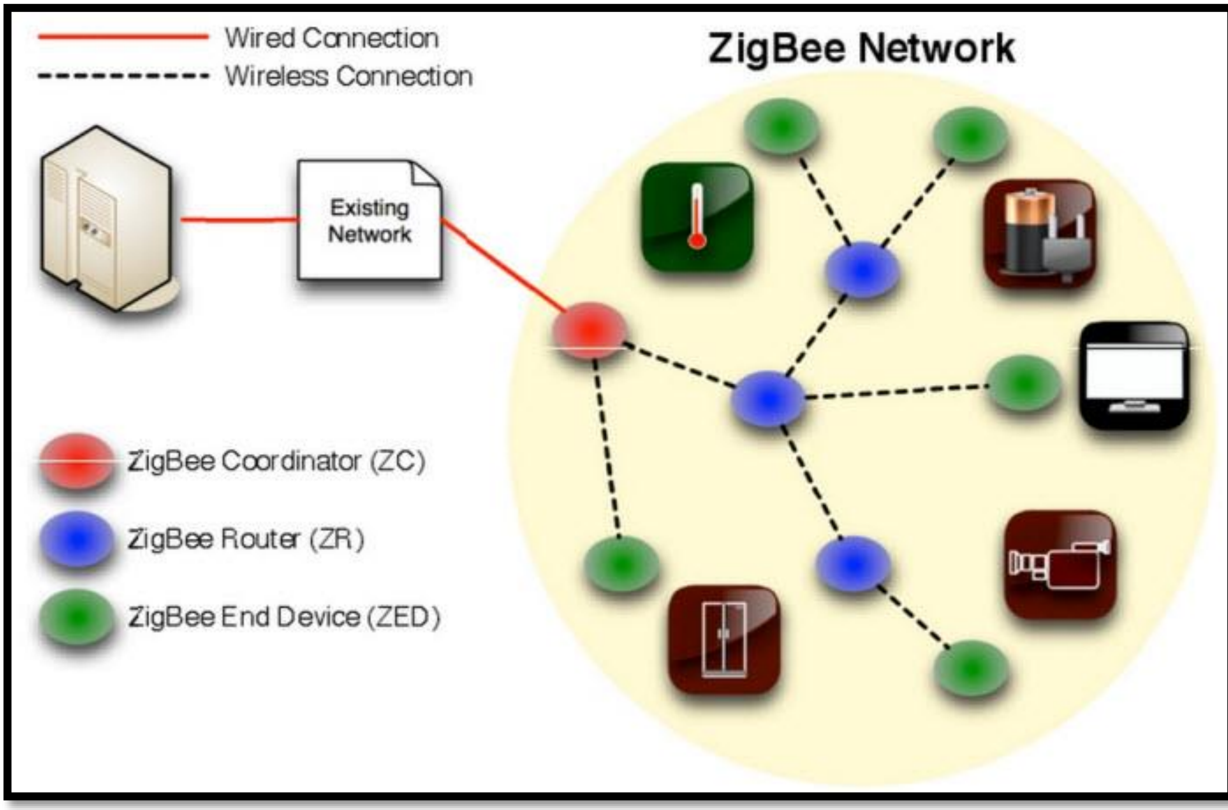

Fig.1.15. Establishment of ZigBee network.

b) Router

The routers are used to improve the coverage area of the network. If suppose one of the routes fails due to the network degradation, it provides backup routers. They routers can provide connection with sink node, base station and other end devices [81]. The routers require same PAN ID as other devices to work within the same network. Router will not go to snooze form.

c) End Device

These devices can execute the transmission or reception a message, but routing function can’t be done. It is connected to either the gateway node or a router.

The end device doesn’t allow the other devices to join the network. The sleep mode nature of the end devices allows the least power consumption. The network can be formed by gateway or sink or co-ordinator node and joining the same network by routers and end devices [82].

1.7.6 The excellency of ZigBee over other devices

Due to the advantages of ZigBee technology like low cost and low power operating modes and its topologies, this short range communication technology is best suited for several applications compared to other proprietary communications such as Bluetooth, WI-FI, etc. Some of these comparisons such as range of Zigbee, standards etc. are given below

	802.15.4	Bluetooth 802.15.1	Wi-Fi 802.11b	GPRS/GSM 1XRTT/CDMA
Application Focus	Many	Cable Replacement	Web, Video, Email	WAN, Voice/Data
System Resource (Protocol Stack Size)	4KB – 32KB (64KB)	250KB+	1MB+	16MB+
Battery Life (days)	100-1000+	1-7	1-5	1-7
Nodes per Networks	255-65K+	7	30	1
Bandwidth(kbps)	20-250	720	11,000+	64-128+
Range (meters)	1-75+	1-10+	1-100	1,000+
Key Market Attributes	Low Data Rate Low Power Low Cost	Cost, Convenience High QoS Low and Guaranteed latency	Speed, Flexibility	Reach, Quality

1.7.7 Programming with the XBee: X-CTU

XBee is a brand of radio that supports a variety of communication protocols. It is a feature-rich RF module which makes it a very good solution for WSN designers; the implemented protocols on the modules like IEEE 802.15.4 and ZigBee can significantly reduce the work by the programmer for ensuring data communication. Besides the capability of these modules to communicate with Microcontroller through UART serial communication, it also has additional pins which can serve for XBee standalone applications. e.g. a router node can be built without the need for a microcontroller. XBee has digital input/output pins that can

be used to read a digital value by a sensor or to control a motor. XBee also has PMW/analog pins; a 10-bit PWM pulse width modulated output may be sent to another XBee. One important feature is line passing where a digital input on one XBee can be reflected on the digital output of another, thus controlling the output of the second XBee.

As discussed earlier, the ZigBee device can be called as XBee and should be configured before deploying the same into respective WSN node. Present work is based on development of wireless sensor network for hazardous gas leakage detection. It comprises WSN node, wherein ZigBee are deployed. It is necessary to configure these devices and hence to configure this devices the Digi corporation has provided an integrated development environment (IDE) called "XBee configuration and Test utility (X-CTU)".Therefore, employing this IDE the ZigBee devices are programmed and then deployed for present WSN.

X-CTU is a Windows-based application provided by Digi. This program was designed to interact with the firmware files found on Digi's RF products and to provide a simple-to-use graphical user interface to them [83]. X-CTU is designed to function with all Windows-based computers running Microsoft Windows 98 SE and above. The window of X-CTU is depicted in fig.1.16.From this figure, you will see four tabs across the top of the program. Each of these tabs has a different function.

The four tabs are:

1. PC Settings: This allows a customer to select the desired COM port and configure that port to fit the radios settings.
2. Range Test: The range test tab allows a customer to perform a range test between two radios.

3. Terminal: This allows access to the computers COM port with a terminal emulation program. This tab also allows the ability to access the radios' firmware using AT commands.
4. Modem Configuration: The modem configuration tab allows the ability to program the radios' firmware settings via a graphical user interface. This tab also allows customers the ability to change firmware versions.

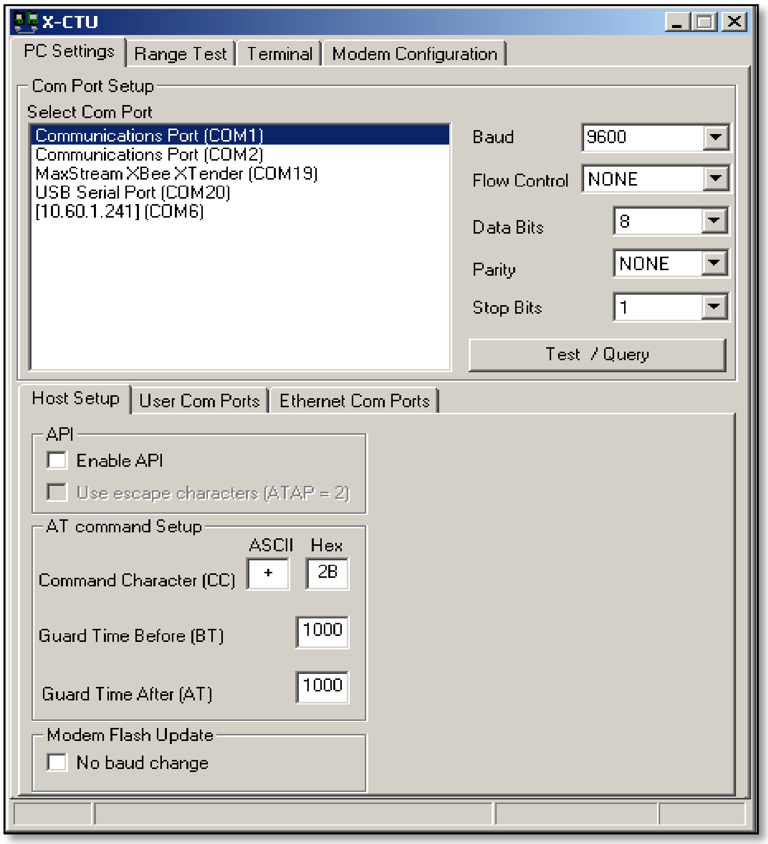

Fig.1.16.The programming tabs of X-CTU.

1.8. Motivation of the Research

In day to day life, environment has the most significant impact pertaining to the health issues. The environment and industry air quality issues are therefore of importance to enhance the awareness and responsibilities regarding the threat on the environment towards public health. Most of the dangerous gases e.g. refrigerant gas and liquefied petroleum gas (LPG), are colorless and odorless

compounds that are produced by the incomplete combustion and need to be detected in order to inform the safety situation continuously.

The literature survey reveals that, many research devotions have been put on gas leakage detection using wired networks.But wired sensors and monitoring systems, however, presents many shortcomings**:** a long deployment time, high maintenance cost, dependence on cable telemetry systems, the inability of cables to resist to various damages, time consuming and expensive, large demand in cable supplies, as well as unavailability of power supplies in remote places to implement the monitoring systems. The answer to these questions is the development of many wireless GPS and GSM based systems to detect the gas leakages.

Therefore, the present research work is aimed to carry out using WSN (Wireless Sensor Network) to replace non-compatible wired network system. Moreover, advanced microcontrollers with low power consumption are available to make smart WSN nodes. Monitoring of the system and GUI created using LabVIEW tool makes the system more interactive, facile and effective compared to reported.

1.9. Objectives of the Research Work

The objectives of this research work are to design, as well assemble and test a dynamic system that can detect the presence of natural and combustible gases and send an SMS alert to the user and nearest disaster management if gas leakage occurs. The dynamic system makes mainly the use of Wireless Sensor Network (WSN). The step programs that would be undertaken are as follows.

1. To analyze a gas sensor for the detection of liquid petroleum gas (LPG).
2. To establish the WSN nodes for gas leakage detection using Arduino nano microcontrollers with XBee.
3. To study the salient features of ZigBee RF module and develop a suitable code for it using X-CTU IDE.

4. To develop a dynamic system that can detect and control the gas leakage and monitor automatically using LabVIEW.

5. Designing of the system will be such that it will be able to send SMS alert to the users.

Taking the above survey into account, we are proposing a system which will be able to detect and also control the gas leakage. In addition, it will be able to alert by buzzer and should send an SMS. In addition, monitoring of the system (wirelessly) would be easy and displayed on the internet using the URL obtained from the web publishing tool. LabVIEW. The interface of the data monitoring with internet server will provide an additional advantage to the users for monitoring the gas leakage area at the long distance continuously.

We planned for a multistep research program and the actual quanta of the work that has been carried out is divided into six chapters.

Chapter I mainly reviews the general concepts and some issues of wireless sensor networks. This chapter includes basics of wireless sensor networks and issues related to wireless sensor networks such as energy efficiency, localization and routing strategy for the deployment of sensor nodes. A detailed literature survey on the development of gas leakage detection and alert system and their applications are also given in this chapter.

Chapter II starts with the discussion of hardware implementation of wireless sensor node and includes details of microcontroller unit and its features. The calibration of wireless sensor node using gas chamber is described in detail. The design and development of PCB and co-ordinator node are discussed.

Chapter III concerns the details of technological platforms and development tools required for a wireless gas sensing system. The details regarding the development of firmware for wireless sensor node with arduino IDE, LabVIEW is also discussed. The programming and flowcharts of wireless gas sensing system are also described in this chapter.

Chapter IV gives detailed studies regarding implementation of wireless system to monitor and control the LPG gas leakage. Designing of the graphical user interface, in LabVIEW environment, is also discussed. The necessary circuit required to control the gas leakage is also mentioned in the same chapter.

Chapter V includes detailed studies of testing and results of received signal strength indicator (RSSI) of ZigBee.

Chapter VI highlights the summary of the research work with the conclusions drawn.

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CHAPTER II

HARDWARE IMPLEMENTATION OF WIRELESS SENSOR NODES

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CHAPTER II

HARDWARE IMPLEMENTATION OF WIRELESS SENSOR NODES

2.1 Introduction

The development in the equipment and our daily life are the major failures to protect the environment against pollution. Consequently, the ecological contamination control and monitoring systems becomes major issue [1]. The environmental and industrial issues create the responsiveness and duty, regarding the hazard on the environment towards human health. The liquefied petroleum (LPG) and its leakage in large amount cause explosive accidents. Therefore, gas leakage detection and alerting are of prime importance. The advanced technologies with exactness and most competent quantity system are need of today's solution [2, 3, 4]. Such gas leakage detection and alert systems are of extremely importance in homes, industries, automobiles, etc. [5].To develop such a hazardous gas leakage detection system, the wireless sensor network system is the only solution today [6] and is a novel class of computing, a new spot of information technology and made up of a large amount of inexpensive micro sensor nodes deployed in a monitored region. Integrated sensor nodes can inspect, collect, process and transmit data of perceivable objects within the coverage of network by perceiving and controlling parameters [7-9]. In sensor network, energy is consumed mainly for three purposes namely data transmission, signal processing and hardware operation [10]. As pointed out earlier, wireless sensor network is a distributed network and hence it becomes more invasive among the industrial, environmental, agricultural and military sectors. It is an innovative technology to avoid hazards associated with the gas leakages [11-14]. According to occupational safety and health administration (OSHA), hazardous gas is that, in which chemicals present in the workplace are capable of causing harm. The chemical term being referred to the dust, mixtures and common materials such as paints, fuels and solvents. In view of the LPG gas limitation, OSHA mentioned

that exposes over 1000 ppm of LPG gas will cause hazards to human respiration system [15]. Therefore, this value is used as the threshold value for the design system under interest.

Jan et al [16] have applied wireless sensor network for carbon monoxide detection and autonomous counter measurement system for a mill. The CO sensor module is connected to a TelosB node and interfaced with ZigBee wireless connectivity to the central controller. The system comprised of the central controller, a high-end PC, connected to the TelosB wireless sensor module via USB and to the actuator circuit through RS232. Somov et al [6] developed a wireless sensor network system for smart gas (CO) monitoring. The system represents an energy management that involves three sensor levels; the network co-ordinator that uses information from the PIR sensor, neighbouring nodes to detect the presence of a gas concentration and modulate the duty cycle of the node and the sensor board, designed with a wireless sensor network (WSN) node that can autonomously send the recorded data wirelessly. The recent addition in wireless gas sensing system is a GPS based WSN systems [17-22].

As discussed earlier, architecture of a Wireless Sensor Network involves the collaborative association of router and co-ordinator nodes [23-25].The reliability of Wireless Sensor Network depends upon the small tiny devices called sensor nodes. These sensor nodes are set with radio interface (ZigBee) with which they establish communication link to form a network. Hence, entire working of a Wireless Sensor Network is dependent on the sensor nodes [26-32].Present work is based on the development of WSN for LPG gas leakage detection and the sensor nodes were developed using an arduino microcontroller. The system consists of both hardware as well as software components. The issues pertaining to hardware components of the WSN nodes are described in this chapter.

2.2 The Wireless Sensor Nodes

A sensor node (also known as a mote) is the fundamental unit of a WSN.

Sensing, processing and communication are the three key elements in wireless sensor networking whose combination in one tiny device gives rise to a sensor node that can store and/or communicate the data over the network wirelessly [33]. The sensor motes are typically low-cost, low-power, small devices equipped with limited sensing, data processing and wireless communication capabilities with power supply. Such small, lightweight and portable sensor nodes are especially designed in such a typical way that they have a microcontroller which controls the monitoring a sensing element (sensor), a radio transceiver for generating radio waves, different type of wireless communicating devices and also ready with an energy source like battery. Distributed over the object, sensor nodes with the necessary sensors make it possible to gather information about the object and control processes which take place on this object. Depending on the application, the sensor node may contain extra hardware parts. Usually sensor node is an autonomous device. Each sensor node in WSN measures some physical conditions such as temperature, humidity, pressure, vibration, and converts them into digital data. Sensor node can also process and store measured data before transmission. The detailed architecture of wireless sensor nodes is described in chapter I.

2.3 The Requirements of Wireless Sensor Nodes

The sensor node is the heart of the Wireless Sensor Network required to perform various applications such as sensing, information gathering, processing etc. The sensor nodes are required to coordinate with other nodes in the network, they have the ability to communicate, measure and actuate in great detail. The combination of sensor nodes creates an ad-hoc network e.g. the nodes can be distributed to an environment and wireless ad-hoc networks can be formed. To make Wireless Sensor Network such thousands of nodes are brought together that communicate through wireless channels for information sharing and cooperative processing. Although each node in the WSN is very limited in energy,

communication ability and computing and storage ability, the WSN has very obvious advantages;

1) They can store a limited source of energy.

2) They have no hassle of cables and have mobility.

3) It can work efficiently under the harsh conditions, and it has large deployment.

4) It can be accessed through a centralized monitor.

5) Communication networks are self-organized with network topology adaptive to various environments.

Hence, without sensor node the Wireless Sensor Network is incomplete.

2.3.1 The microcontroller unit for WSN node

The microcontroller plays a key role in the field of WSN technology. The salient features of microcontroller decide the reliability of the WSN node [34, 35]. Going through the literature survey, it is found that there are various families of microcontrollers such as PIC [36, 37], AVR [38, 39], ARM [40-42], LPC [43, 44], MSP [45,46,47] etc those have been adopted for deployment of the Wireless Sensor Networks. In the present system, it is decided to use the arduino platform or microcontroller for the deployment of WSN nodes. Also, there are many other microcontrollers and microcontroller platforms available for physical computing e.g. Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. The use of an arduino simplifies the process of working with microcontrollers and additionally it offers some advantages to the users (teachers, students, and interested amateurs) over other systems such as cross-platform, simple, clear programming environment, open source and extensible software and hardware. Arduino platform has good specifications e.g. cheap, easy to use and wide varieties of shields that have been emerged with many different purposes such as Ethernet and GSM support.

a) The salient features of an arduino nano microcontroller (ATmega328)

The ATmega328 is an embedded board having included USB competence. The miniature and user responsive nature makes it more superior than other advanced microcontrollers. These microcontrollers have more on chip facilities such as +5V, analog and digital pins. It doesn't have on board power jack. Due to the auto switching capability of ATmega 328 microcontroller, no external power jumpers are required. It posses various on board pins and has superior features as follows:

- It has automatic reset
- LED indicating power satisfactory.
- On board transmission and reception LED's
- Switching automatically to input power.
- On board USB facility for serial communication
- Reset can be done manually by pressing on board reset button.

The arduino nano controller has following features as:

- ✓ The operating voltage is 5V.
- ✓ The suggested input voltage is 7-12 V.
- ✓ It has 14 digital input/output pins out of which six pins provides PWM facility.
- ✓ There are normally eight analog pins.
- ✓ The current handling capability of this controller is approximately equal to 40 mA.
- ✓ It has on board 32 KB flash memory, 2 KB SRAM and 1 KB EEPROM.
- ✓ The crystal clock required for this controller is 16 MHz.
- ✓ It is portable in nature.

Therefore, the present WSN nodes are designed using arduino nano-microcontroller.

b) The pin description of an ATmega328 microcontroller

The pin description and pin layout of arduino nano microcontroller are depicted as follows (fig. 2.1 (a,b)).

Pin No.	Name	Type	Description
1-2, 5-16	D0-D13	I/O	Digital input/output port 0 to 13
3, 28	RESET	Input	Reset (active low)
4, 29	GND	PWR	Supply ground
17	3V3	Output	+3.3V output (from FTDI)
18	AREF	Input	ADC reference
19-26	A7-A0	Input	Analog input channel 0 to 7
27	+5V	Output or Input	+5V output (from on-board regulator) or +5V (input from external power supply)
30	VIN	PWR	Supply voltage

Fig. 2.1(a). Pin description of an arduino nano microcontroller.

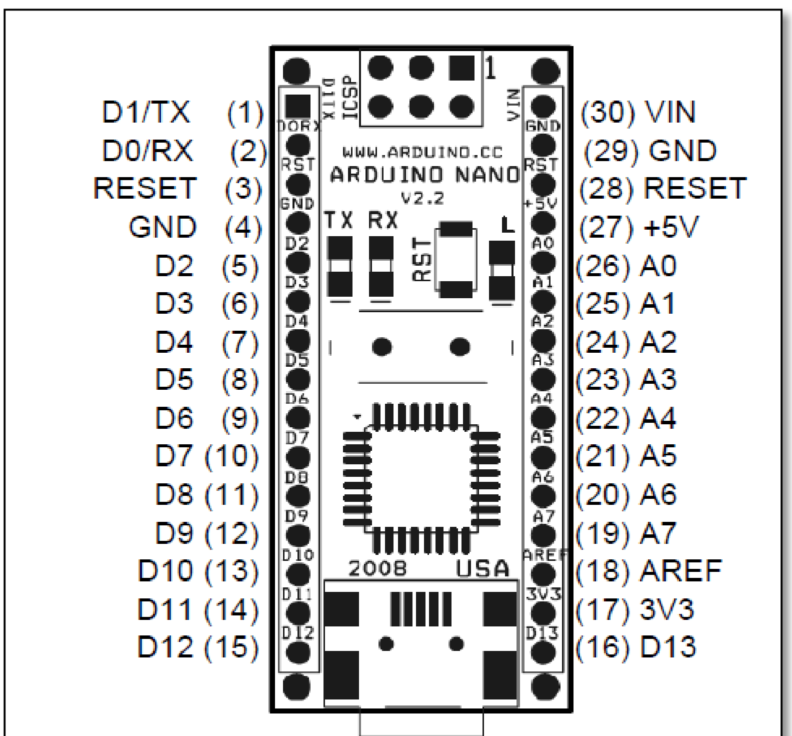

Fig.2.1 (b). Pin layout of an arduino nano microcontroller.

c) The I/O ports

The I/O pins of arduino nano microcontroller can be programmed using various functions available in arduino IDE. The 5 volt is required to operate the microcontroller. Each pin has an internal pull-up resistor of 20-50 KΩ. The workings of some pins are summarized below.

- **Serial pins -** These pins are used for transmission and reception.
- **Exterior interrupt pins -** It is used when external interrupts becomes active.
- **PWM pins-** It provides PWM facility to the controller using 3,5,6,9,10 and 11.
- **Serial Peripheral Interface –** The Serial Peripheral Interface communication is possible through the pins available on board.
- **LED: 13-** The board uses digital pin 13 as LED.
- **I^2C: (SDA) and (SCL) –** The I2C (TWI) communication is possible using wire library.

d) The reset circuit

Through the software running on a computer, any program may allow to reset on arduino nano board. The reset circuit uses a 100 nf capacitor. The uploading of code can be done using upload button in the arduino IDE [48]. When the nano is connected to laptop/computer, it resets each time (via USB). For the following half-second or so, the boot loader is running on the nano. If a sketch running on the board receives one-time configuration or other data, when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

2.3.2 The hardware components

Few parts of hardware for a wireless gas sensing and controlling system are an exhaust fan and a buzzer and its interfacing circuits. In this section, the design of a system and function of each component and its interfacing to arduino

is discussed. Actually the gas sensing unit required for sensor calibration is described in this section. Additionally, power supply unit developed for sensor and sink node is also deals with this section.

a) The gas sensing and the unit

In this, a gas sensing apparatus to achieve the sensing mechanism is discussed.

1. The gas sensing

The device which converts physical quantity into electrical quantity is a sensor according to the Instrument Society of America. The different definitions and diverse views about the sensors have been adopted by scientists and engineers. Also sensor is a device which converts one form of energy into other form. Normally, the sensors are grouped according to their signals are received and generated [49]. The sensors are classified according to the energy generated or received by them. Sensors categorization is enormous field, can't be classified on one criterion e.g., they are classified according to its relevance, the fabric and the property used by itself.

The sensors are active or passive in nature. To obtain and quantify the signal, passive sensor is used. An active sensor is used for measuring signals transmitted by the sensors that were reflected, refracted or scattered. Based on the transmission of signals, active or passive sensors are classified. The vital properties of sensors are summarized below.

- ✓ The time taken by the sensor
- ✓ How sensors are reproducible
- ✓ An aging effect of the sensor
- ✓ The sensitivity and stability possessed by the sensor
- ✓ dynamic range
- ✓ selectivity
- ✓ size, weight and cost.

The response time of a sensor is the time taken by the sensor to reach 90% of its steady state output value after the introduction of the measurand, whereas the recovery time is the time taken by a sensor to be within 10% of the value it had before the exposure to the measurand. The sensor with less response time and recovery time is considered to be a good sensor. The ability of the sensor to produce the same characteristic upon the repeated exposure to a particular measurand is referred to as it's reproducibility. The sensor with excellent reproducibility will have the same recovery time, response time as well as the same response for a particular measurand. However, there is some degradation on the sensor signature after a long use of the sensor and it is natural. The time taken by a sensor for it's degradation is commonly known as aging. Sensitivity and resolution are the critical properties of a sensor for the application with the precise measurement system or for the application sensing the potentially dangerous measurand. The smallest change in the measurand that a sensor can detect is the resolution of the sensor and the change in the output per unit change in the measurand is the sensitivity of the sensor. The importance of properties of a sensor depends on the application where the sensor has to be used. For example: In the detection of highly toxic gas, sensitivity is the important property, in online control system where the measurand is exposed repeatedly. Reproducibility and aging are the important properties wherein as application relating to the implantation of biosensor in the animals, weight and size becomes the important issues.

2. The gas sensing unit

The gas sensing unit is a cylindrical leak proof metallic (good quality stainless steel) chamber of volume around 250 cm^3. It's typical dimensions are 8.6 cm X6 cm. It is fitted on a metallic base of dimension16.5cm X 15 cm. The chamber was made leak proof using the metallic and rubber O-rings fitted tightly to the chamber by a screw arrangement. A provision was made for inletting the

calculated quantity of gas into the chamber by a metallic (S.S) capillary (I.D. ≅ 2 mm. The electrical contacts were made to the sensor for the measurements and the sensor was placed inside the chamber. The measurements were made at room temperature (299K).

Fig. 2.2. The gas sensing unit.

b) Circuit for the gas sensor

The present wireless gas sensing system uses MQ-2 gas sensor for the detection of LPG gas [50]. It is an ideal sensor to detect the presence of a dangerous LPG leak in our home or in a service station, storage tank environment and even in vehicle which uses LPG gas as its fuel.

Fig.2.3. MQ-2 gas sensor.

This unit can be easily incorporated into an alarm circuit/unit, to sound an alarm or provide a visual indication of the LPG concentration. The sensor has excellent sensitivity combined with a quick response time. When the target combustible gas

exists, the sensor's conductivity goes higher with the gas concentration rising. The gas sensor circuit diagram is shown in fig. 2.4.The three output pins of this sensor are V_{CC}, GND and V0 pin. R_L used in figure 2.4 is 20 KΩ. The load resistor (R_L) is connected between heating coil terminal and one of the input pins.

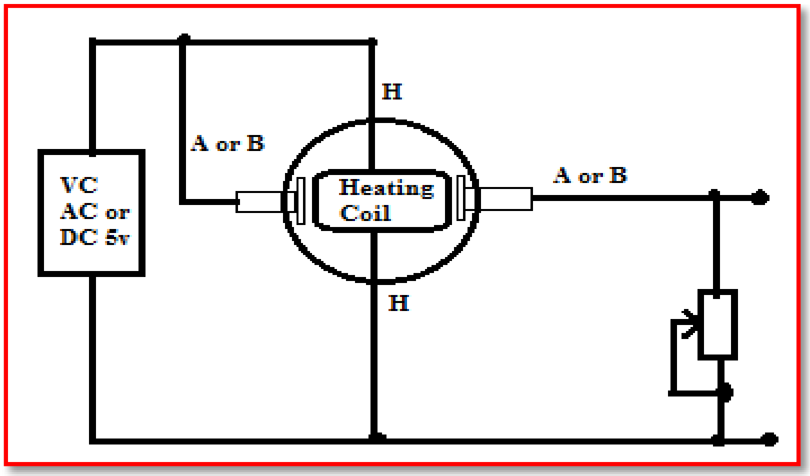

Fig. 2.4. Gas sensor circuit diagram.

The sensor's resistance between R_s and R_L form a voltage divider. Based on the data provided in the MQ-2 data sheet, R_s is determined in the clean air under given temperature and humidity constant. The fig. 2.4 also shows the sensor out come with 6 pins. The coil of the gas sensor is shown by pin H. The connection between pin A and B to the sensor is shown in fig.2.4.

Figure 2.5 below shows the gas sensor connection to the arduino pins. The sensor is connected to analog pin A_0 of arduino, read the output in the form of voltage from the sensor respectively. For stable operation of sensor the more heating of the coil is required.

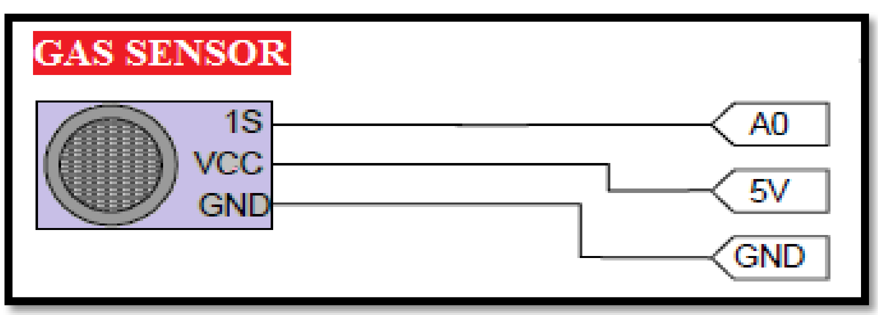

Figure 2.5. The gas sensor connection to arduino pin.

- ❖ The coil of the sensor consumes more power.
- ❖ To operate the senor 5 V is required.
- ❖ The arduino gets powered through its jack available on board itself.

c) The output circuit connection of wireless gas sensing system

It consists of the following hardwares:

1. The connection of buzzer to the system
2. The exhaust fan connection and
3. The ZigBee connection.

The purpose of the above hardware is to alert, prevention of accidental attacks and wireless communication among the motes. The alerting to the users is possible only after the gas concentration beyond the towering concentration. The threshold level limits with respect to sensor output voltage is shown below.

Gas concentration in ppm	voltage range in volts
≤400 ppm	<1.5V (normal level)
400ppm - 800ppm (lower exposure limit)	≥1.5V TO _ <4.2V (low level)
≥800 ppm (upper exposure limit)	≥4.2V (explosive level)

When the gas concentration is beyond 800 ppm, start buzzering to alert the users that the neighboring areas have entered in hazardous situation and tragedy emigration is needed. When the gas attention reaches between 400 ppm- 800 ppm the fan will turn on to indicate the caution stage and it sucks out the gas outside the leakage area as the precautionary measures against explosion attacks.

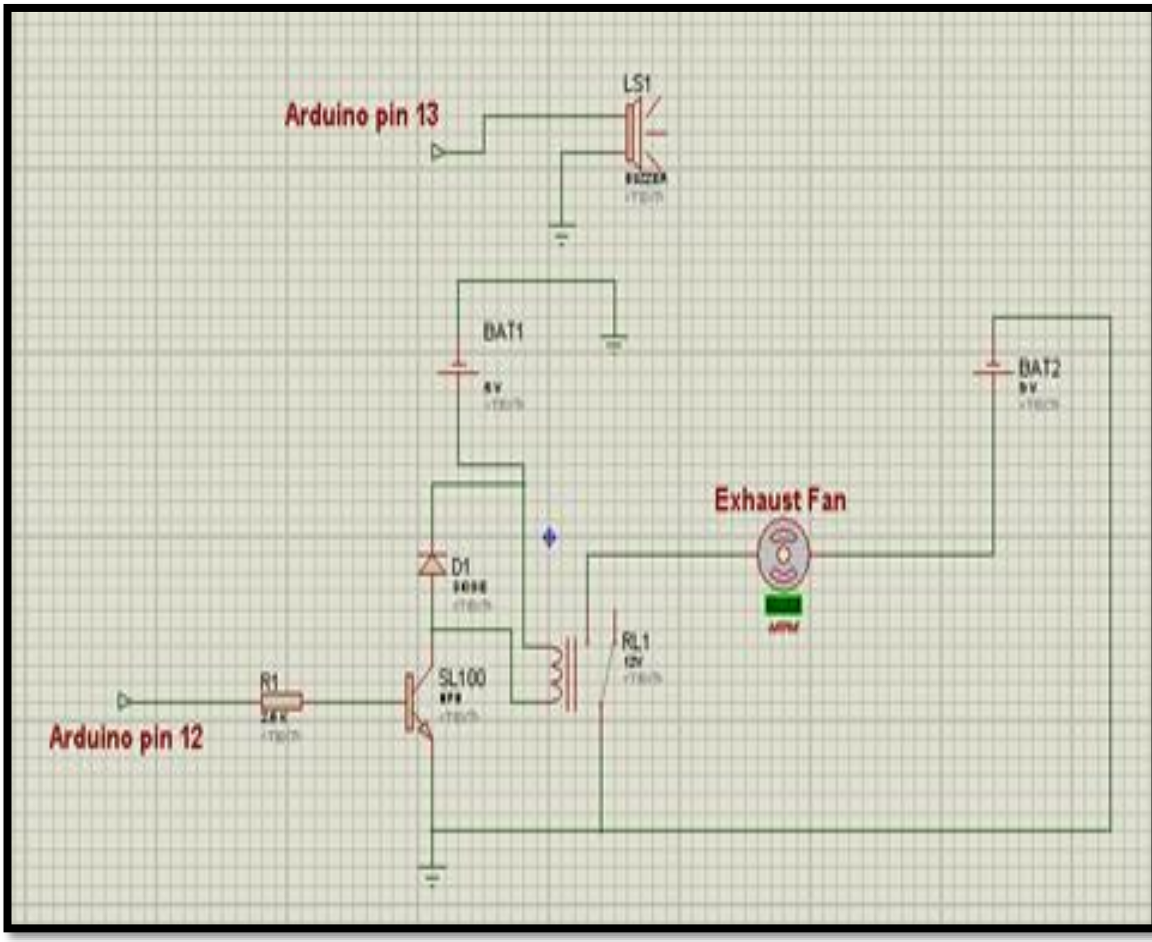

Fig.2.6. The hardware connection circuit.

Figure 2.6 shows the hardware connection circuit which shows the buzzer and exhaust fan connection to arduino. The arduino pin 13 is connected to alarm system and exhaust fan connection to arduino pin 12. The transistor SL100 is used as bridge between controller and fan because operating voltage of both is different. Here, the relay provides a 9V to the exhaust fan. Before installing the entire circuit, Relay should be checked whether it is normally open or closed. After getting the signal from arduino pin, the exhaust fan is turned because it is in normally open mode. Lastly, the hardware circuit from the arduino is connection of ZigBee. The ZigBee connection to arduino is shown in fig.2.7. The data from the sensor nodes is transferred to gateway node using ZigBee, interfaced with LabVIEW for monitoring of the data.

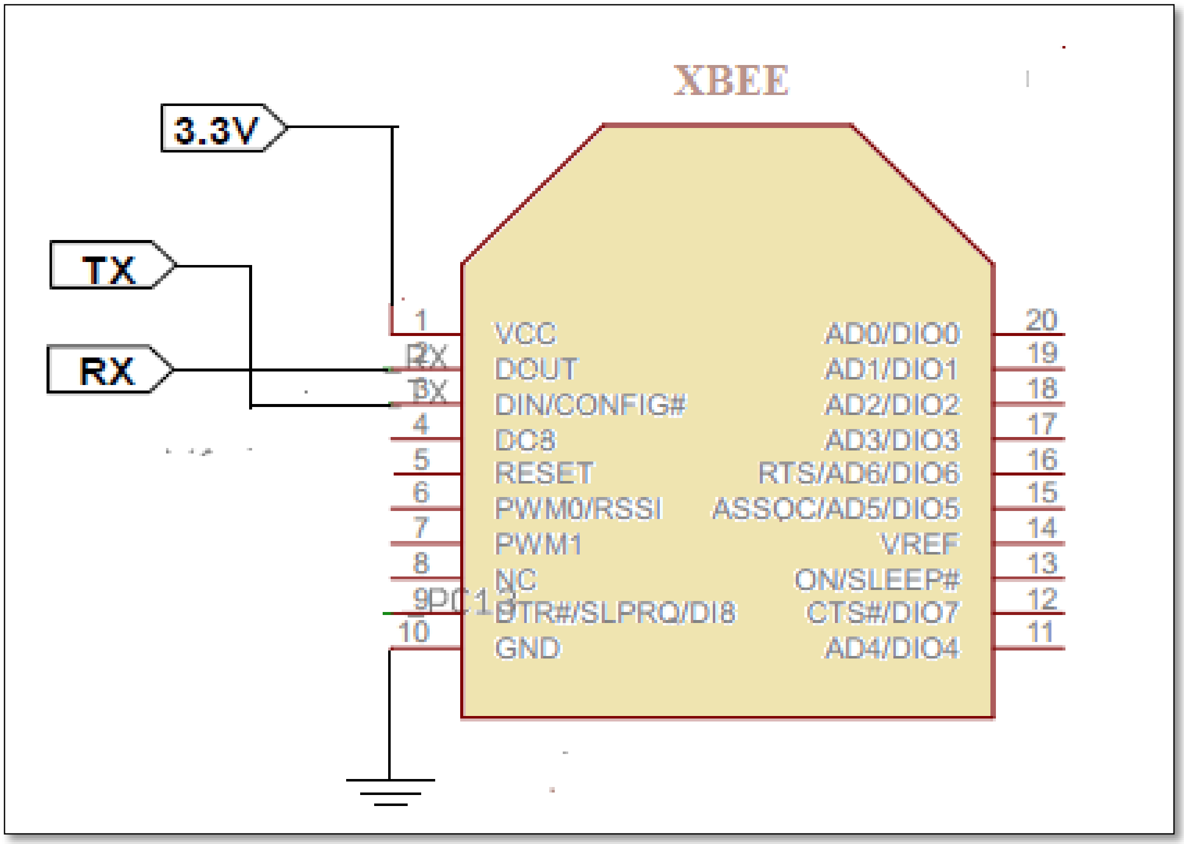

Fig.2.7.ZigBee output diagram.

2.3.3 The development of PCB for the system

The final step of the hardware part is the PCB development of the system. The PCB is designed with the Express PCB software package. This software is especially used for PCB design. For the PCB development, copper clad or PCB board is used. The bread board connection was installed first before developing the entire PCB. Copper clad board provides permanent connection among the components; they can remove only after de-soldering it. For providing the permanent connection soldering is effective method. As well, banana pins was used as a jumper wires.

2.3.4 Power supply unit for wireless sensor node

Our system works on +5V power supply in which microcontroller and LPG sensor work. The XBee unit requires (for RF communication) +3.3 V [51-52]. For establishment of wireless gas sensing system, the WSN nodes should be located at

specific locations within the room. To deploy these WSN nodes, at different places, it is essential to provide battery back-up. Therefore, the deployment of DC rechargeable batteries is made. Each node is associated with its own battery of 12 V. The WSN nodes consist of XBee unit which consumes rather high power. Therefore, it is essential to charge these batteries frequently. It is observed that, batteries could be used for 09 hours in continuous mode. The power supply unit for WSN node is shown fig.2.8.

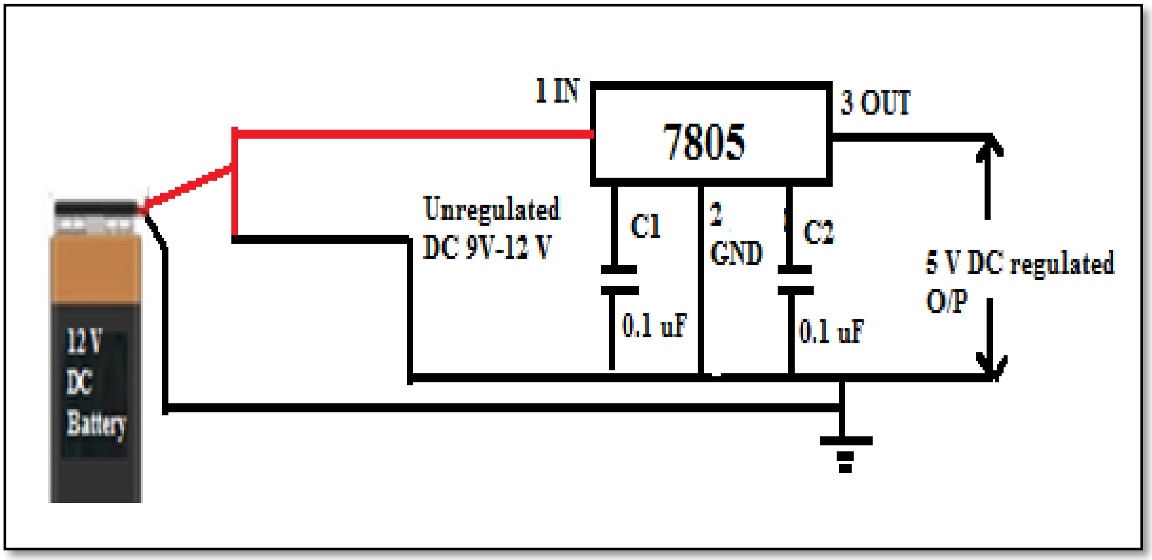

Fig.2.8. Power supply unit for wireless sensor node

2.3.5 The hardware components for co-ordinator node

The receiving section consists of a co-ordinator node and a pc or laptop. The co-ordinator node of a wireless sensor network has the same structure as that of the sensor node except sensor module. It is responsible for establishment of the network, information reception, aggregation, processing and sending control instruction and implementation. The coordinator node has ZigBee module to receive the information from the sensor node and send it to the arduino microcontroller. The microcontroller sends this collected data to the PC using a USB cable to update the values of monitoring sites in the PC. Using a single co-ordinator, a network with four sensor nodes is developed. The co-ordinator node communicates the sensor node through the GSM modem.

It consists of: a) XBee module b) Arduino Microcontroller c) Arduino GSM shield d) Buzzer e) Power supply unit.

a) The XBee module

The ZigBee device is programmed as a co-ordinator using X-CTU IDE tool as described in chapter I. It includes the networking and security, RF interfacing, serial interfacing, I/O settings, diagnostics, and AT command options [53]. The ZigBee works with IEEE standards. The co-ordinator XBee module extracts data from the transmitter module and sends to the PC through arduino controller.

b) An arduino board (ATmega328 microcontroller)

An arduino UNO is used; serial communication is possible easily because of integrated USB facility [54]. The board posses 2K RAMS. In addition, the logical decision regarding to alert and control is done using it. The XBee is able to perform any application without microcontroller, it is optional. But it can’t take any logical decision like microcontroller; only fruitful wireless communication is possible. To carry out these restricted decisions arduino UNO microcontroller is used at the sink or gateway node. Beside this, compatibility of GSM shield for sending SMS on user mobile phone, least power makes these most favorable than available controller in the market. Also, it provides compatibility with other shields available with Arduino which makes it enormously adaptable and accessible.

c) The GSM module

The Arduino GSM shield is a compatible to UNO board, therefore used to send alert SMS on user mobile phone after detecting the gas leakage. The shield is programmed using arduino IDE [55]. The programming is done using AT commands [56]. The SIM card from GSM mobile is only applicable. The connection of shield pins 2 and 3 is given to an Arduino UNO. Pin 2 is connected to TX of the UNO’S and vice versa.(fig. 2.9).

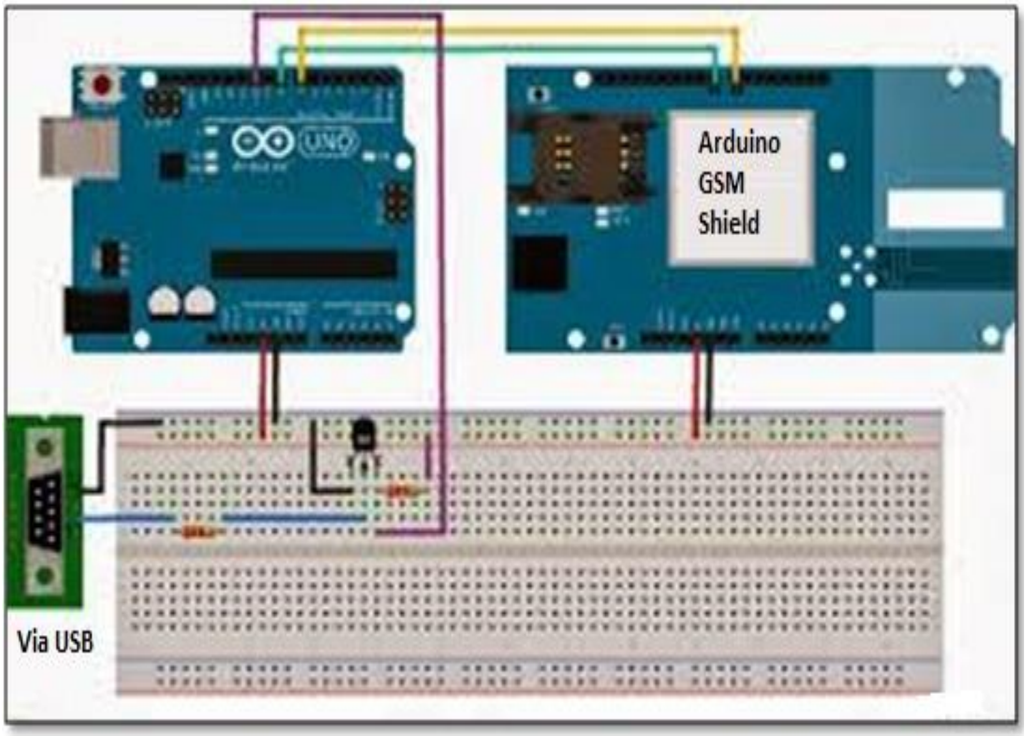

Fig.2.9. Arduino GSM connection to Arduino UNO board.

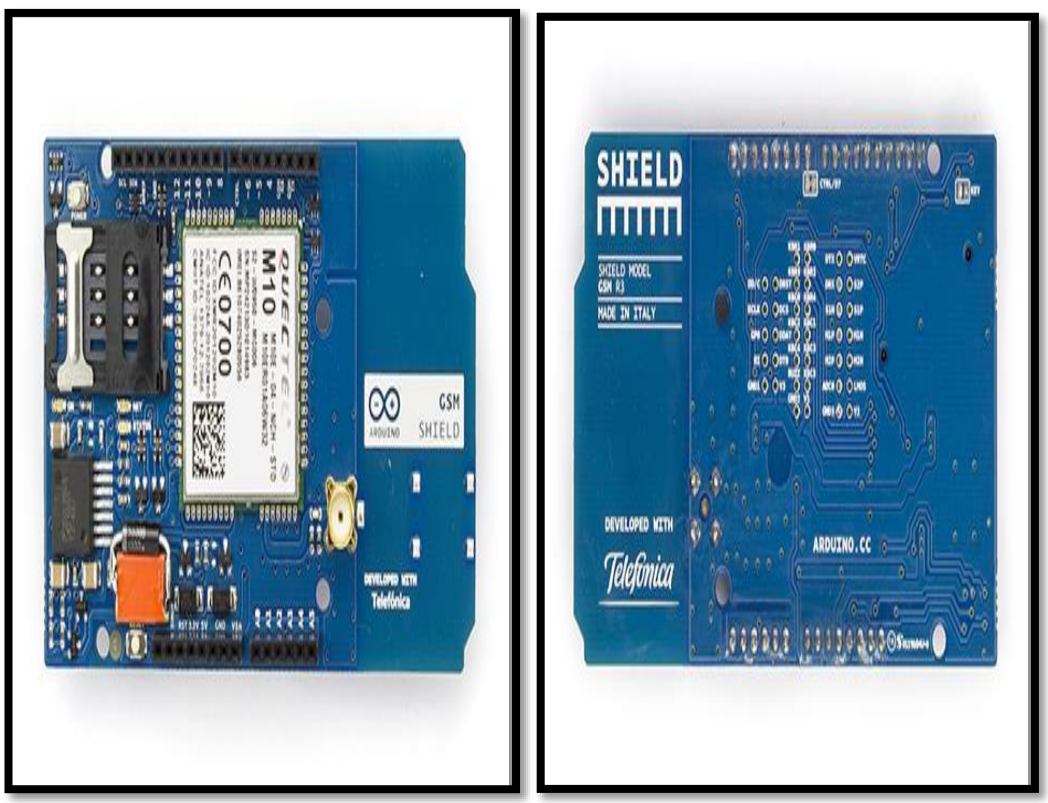

Fig. 2.10. An Arduino GSM shield: front and back view.

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Fig.2.11.Connection of GSM Shield to the arduino UNO.

d) The buzzer

The buzzer is used as an acoustic signaling device. It is used for alerting the peoples in the form of alarms, as timers for various applications. We proposed a buzzer having piezoelectric element. The buzzer is ON only after getting the signal from the microcontroller. When the gas concentration goes beyond its explosive limit, the alarm circuitrary works.

e) Power supply unit

The co-ordinator node consists of XBee unit, which requires 3.3V, given from arduino board having on board 3.3V supply. An arduino gets power from its USB cable. The power supply unit for co-ordinator is shown in fig.2.12.

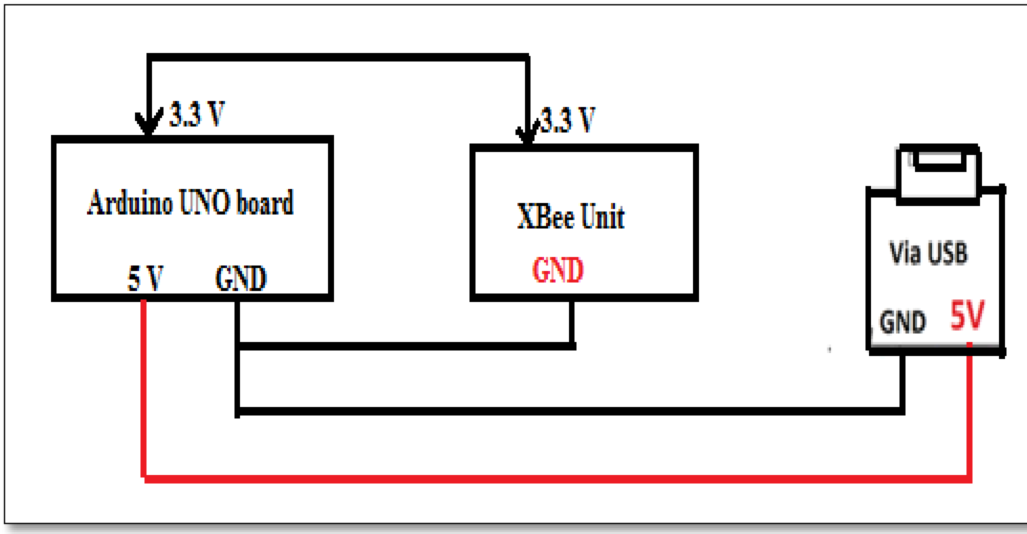

Fig.2.12. Power supply unit for co-ordinator node.

2.3.6 The PC/Laptop for visual interpretation

The PC/Laptop is connected to co-ordinator node for visual interpretation. The coordinator node allows data collection over ZigBee, and result will be displayed on the laptop. The monitoring of the data is done on it.

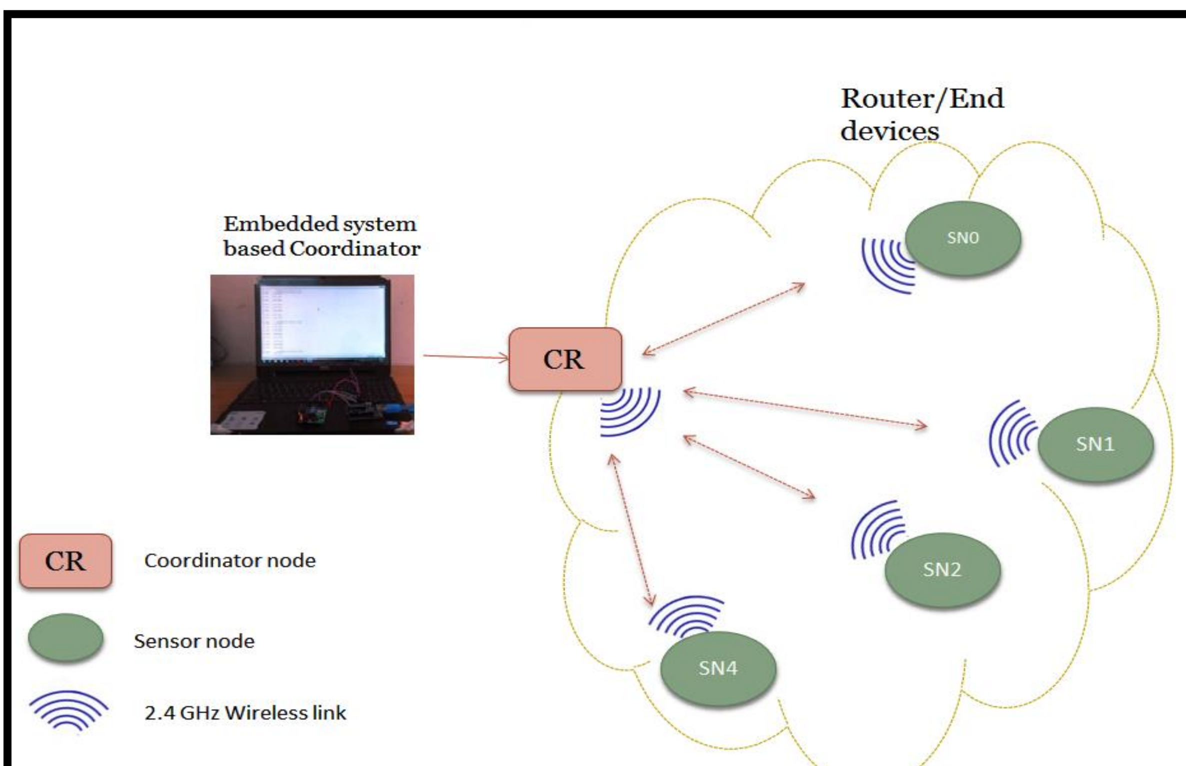

Fig. 2.13. The PC/Laptop for visual interpretation.

2.4 Methodology

Our system focuses more on the detection and monitoring of the LPG gas leakage. The microcontroller will continuously receive the data from the sensor in an analog packet of data. The microcontroller will process the data and convert it into ppm. The converted data will be displayed on the front panel of the LabVIEW. Whenever the reading of the sensors exceeds the limit set, it will automatically send an SMS alert wirelessly using GSM network to the numbers (mobile) as being set on the source code. The methodology shows the step by step taken in order to complete the gas sensing and mentoring by a wireless gas sensing system. It also includes the planning, the development in the design and the continuous monitoring of the system.

2.4.1. The calibration of wireless sensor node

Calibration is an essential process to be undertaken for electronic instrumentation. It is a simple process that consists of reading the standard and test instruments simultaneously when the input quantity is held constant at several values over the range of test instrument. While calibrating, it is customary to take readings both in ascending and descending orders. Hence, to represent the values of the parameters one should calibrate the system precisely, so that the exact values could be outputted from the system under investigation. Each wireless sensor node is designed for monitoring of LPG leakage detection of wireless gas sensing system. The process of calibration is discussed through the following procedure.

Calibration of Wireless Senor Node for MQ-2 gas sensor

The calibration of Wireless Sensor Node is carried out to find out a relationship between output voltage (sensor) and gas concentration in ppm. For precise calibration, the LPG gas of different volumes are applied to the sensor. This is done using 250cc air tight gas chamber [57]. The LPG was inserted in it using a standard medical syringe.

Fig. 2.14.Experimental arrangement of Wireless Sensor Node for LPG leakage measurement.

The relationship between gas concentration and sensors output voltage can be calculated by using following formula.

$$\text{Gas concentration} = \frac{10^6}{\text{Volume of gas chamber (250 cc)}} \text{ x Volume of gas inserted}$$

The data obtained using this formula are tabulated as follows.

Gas concentration (ppm)	sensor output voltage (volt)
200	1.05
250	1.1
300	1.2
350	1.28
400	1.33
450	1.45
500	1.51
550	1.58
600	1.72

650	1.91
700	2.3
750	3.0
800	3.5
850	4.1
900	4.2
950	4.35
1000	4.4
1050	4.5
2000	4.5
2050	4.51

A graph is plotted as gas concentration (ppm) vs sensor output voltage.

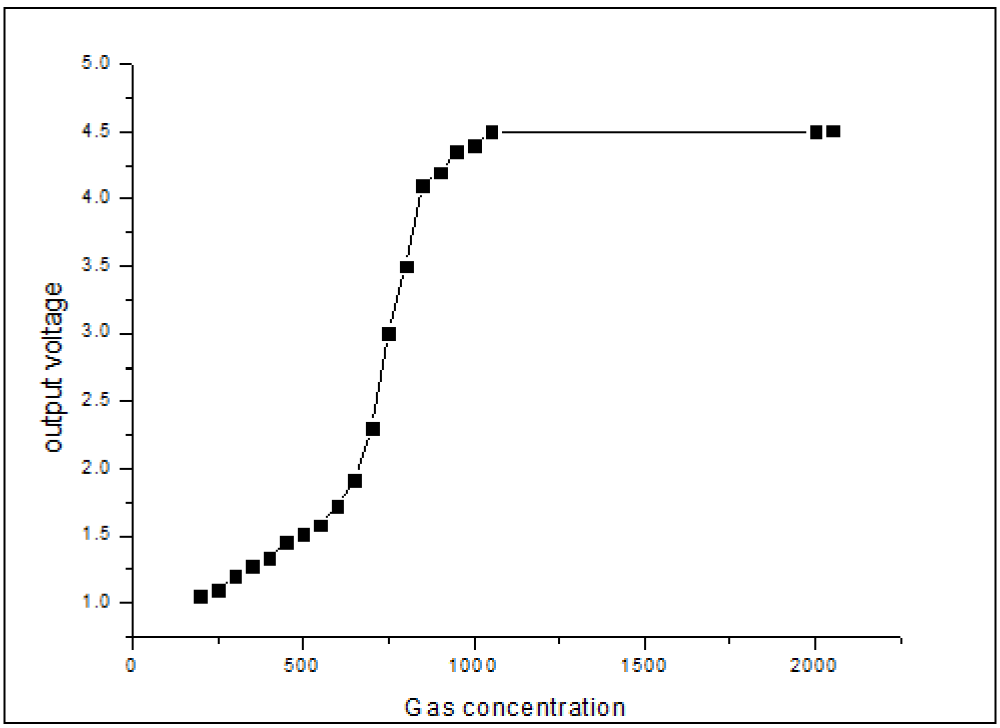

Fig. 2.15. Plot of gas concentration vs sensor output voltage.

2.4.2. The design of WSN nodes for hazardous gas (LPG) leakage detection and measurement: hardware implementation

The LPG which is a highly flammable mixture of hydrocarbon gases, used as a fuel in many applications like homes, hostel, industries, automobiles, vehicles

because of its desirable properties that include high calorific value, which produce the less smoke and soot and does not cause much harm to the environment. Natural gas is another widely used fuel in homes. Both gases burn to produce clean energy, however there is a serious problem associated with their leakage in the surroundings. The gases being heavier than air do not disperse easily and may lead to suffocation when inhaled. Also gas leakage into the air may lead to explosion. These days explosion of LPG gas has been increased and to avoid this, there is a need for the system to detect and also to prevent leakage of LPG. Gas leak detection is the process of identifying potentially hazardous gas leaks by means of various sensors. These sensors usually employ an audible alarm to alert people and SMS alert to the users when a dangerous gas leaks.

Fig. 2.16.depicts the block diagram of a wireless sensor node and fig.2.17 depicts the circuit schematic of a wireless sensor node.

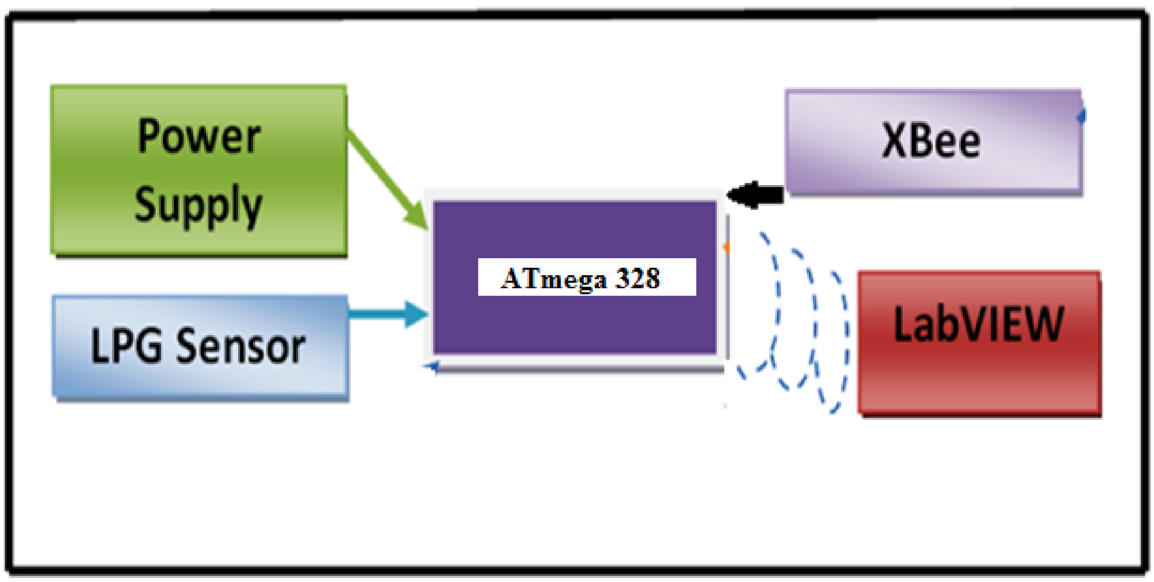

Fig. 2.16. Block diagram of a wireless sensor node.

To design a wireless sensor node for LPG gas leakage measurement, MQ-2 gas sensor is employed. Sensitive material of MQ-2 gas sensor is SnO_2, which has lower conductivity in clean air. We have used a load resistance of about 20KΩ. As the conductivity increases, and resistance of sensor changes with the concentration

of combustible gases, a simple electronic circuit can be used to convert the change in resistance to change in concentration of the combustible gases. The sensor works with a 5 volt power supply.

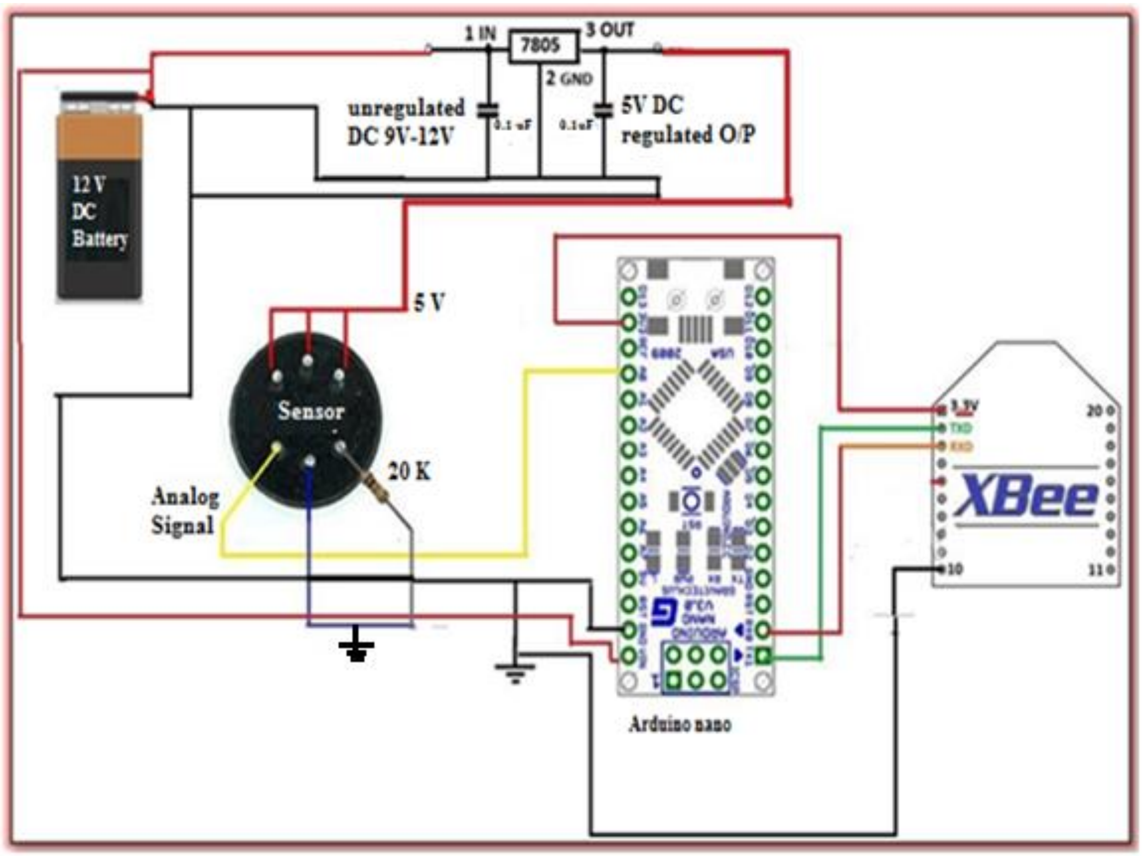

Fig.2.17.The circuit schematic of a wireless sensor node.

The typical characteristics of a MQ-2 sensor are as follows:

Model No.	MQ-2
Sensor Type	Semiconductor
Detection Gas	LPG
Concentration range	200-5000 ppm
Load Resistance	20 KΩ(5 KΩ -47 KΩ)

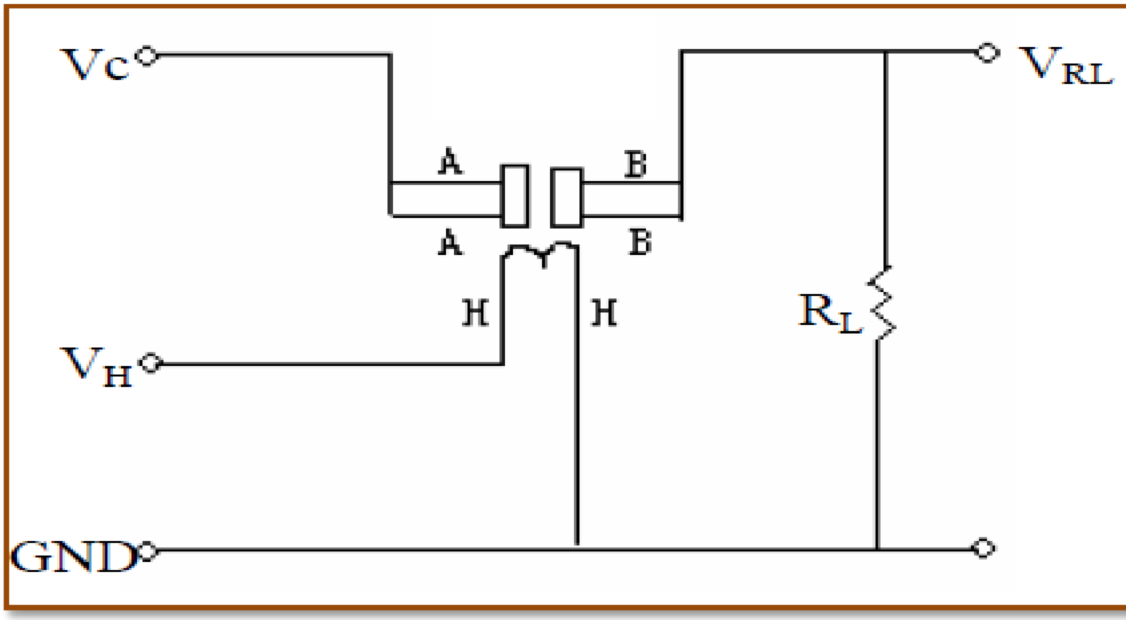

Fig.2.18. An electronic circuit to convert the change in resistance to change in gas concentration.

2.4.3 The design of co-ordinator node: hardware implementation

Fig.2.19. depicts the block diagram of a co-ordinator node. The hardware of the co-ordinator reveals the interfacing of it to the personal computer.

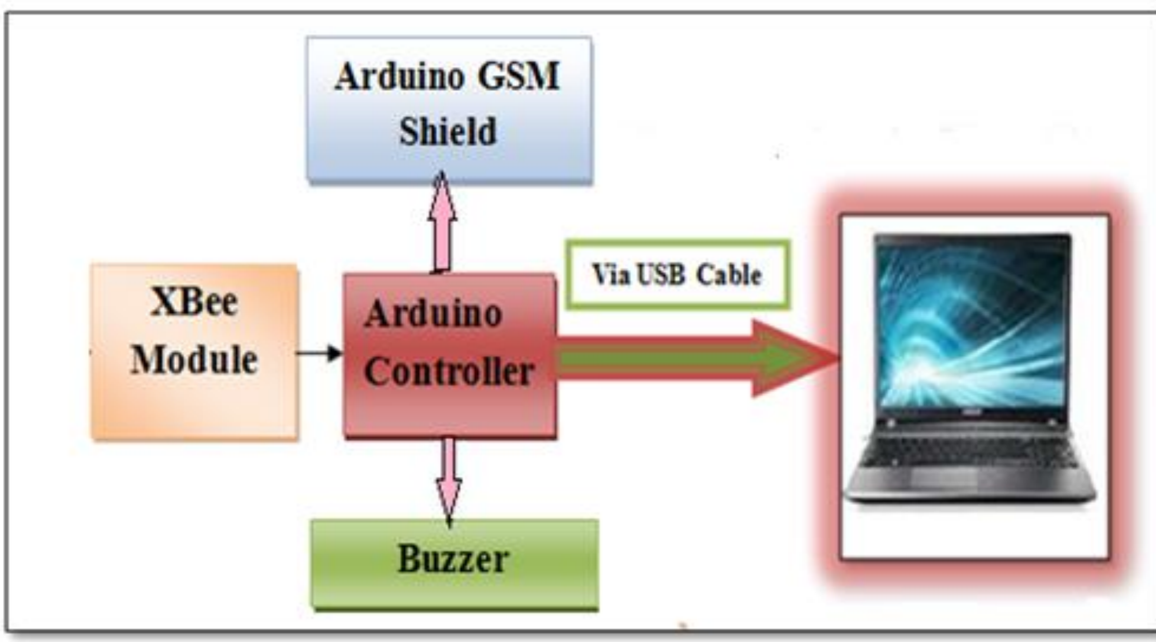

Fig 2.19. Block diagram of a co-ordinator node

The circuit schematic of a co-ordinator node is shown in fig. 2.20.

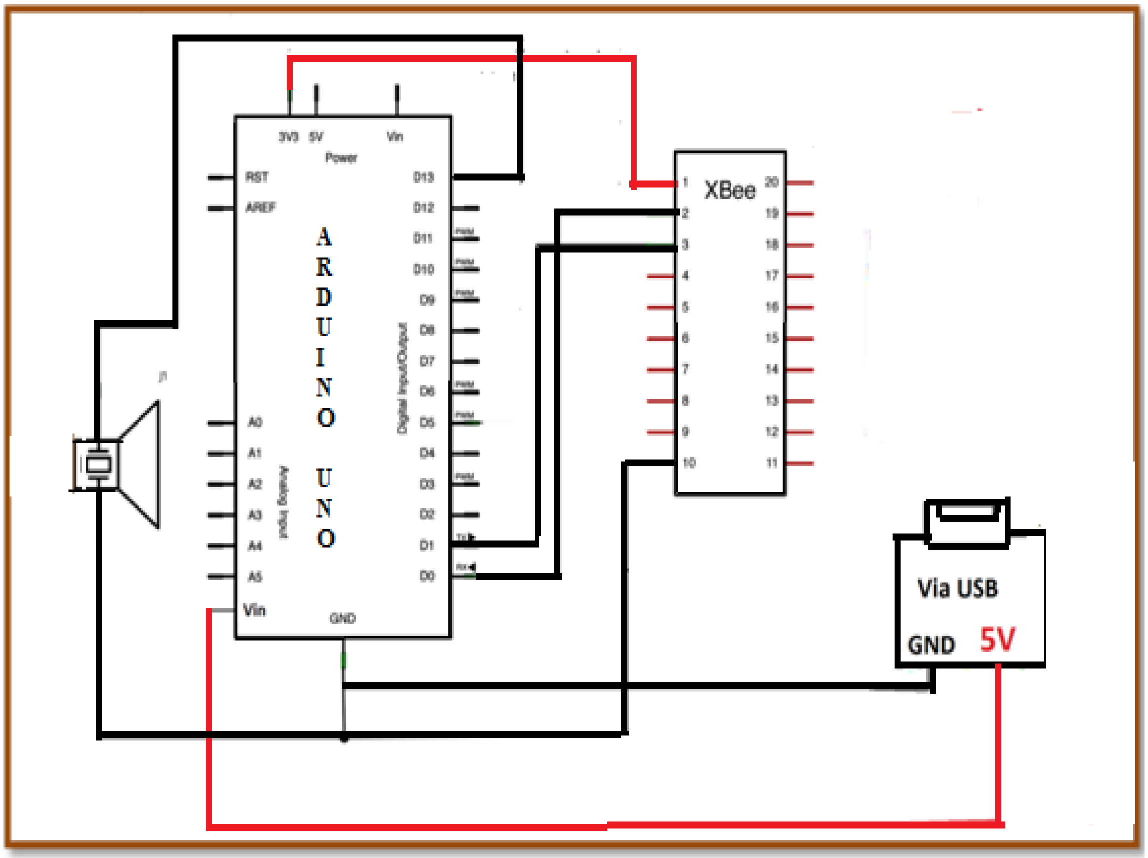

Fig. 2.20.Circuit schematic of a co-ordinator node.

2.5 Conclusions

The properties of wireless sensor networks allow faster deployment and installation of various types of sensor nodes because many of these networks provide self-organizing, self-configuring, self-diagnosing and self-healing capabilities to the sensor nodes. It also offers mobility and flexibility in connectivity which promotes network expansion when needed. Moreover, an arduino UNO and nano microcontrollers can be employed to build WSN nodes. The RF module XBee was used in both sensor and co-ordinator nodes for secured data transmission and reception. The leakage detection of LP gas can be made alert to the user by activating the buzzer.

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CHAPTER III
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CHAPTER III

TECHNOLOGICAL PLATFORMS AND DEVELOPMENT TOOLS

3.1 Introduction

The technology of Wireless Sensor Networks (WSNs) is in the front part of the investigation of the computer networks and it could be the next technological market of a huge sum of money [1]. Sensor nodes have limited processing power, storage, bandwidth and energy. This limitation makes provision of the security in sensor networks, not an easy task [1]. The availability of cheap, low power and miniatured embedded processors, radios, sensors and actuators, often integrated on a single chip, are leading to the use of wireless communication and computing for interacting with the physical world in applications such as wireless gas sensing system. As sensor nodes as well as co-ordinator reveal the embedded philosophy, both hardware and software should be co-designed. To perform this pre-defined task, microcontroller has to play with the real world. For this purpose, embedded software is required. The present WSN sensor nodes are designed using an arduino microcontroller and hence software required for the present system is designed in python environment using an Arduino IDE, ZAP 2.0.5.

As the sensor nodes are embedded systems, they should work stand alone. For this purpose one has to employ a proper operating system. To furnish the needs of an operating system, the present system makes the use of super loop [2-4]. To develop the firmware, the development tool must consists of tools such as compiler, an assembler, editor, debugger, simulator, emulators, etc [5-8].The present system uses XBee for wireless communication; therefore, the firmware should cover the function of wireless communication. The co-ordinator node is interfaced to the laptop and develops an effective GUI for it using LabVIEW tool. The chapter deals with software development of a wireless gas sensing system.

3.2 The Programming Tools

The LabVIEW and an Arduino IDE are the programming tools used for this

system. But, the writing programming is mostly used in arduino. Meanwhile, LabVIEW uses a programming type of block diagram.

3.2.1. An arduino integrated development environment

An integrated development environment (*IDE*) is a software application that provides comprehensive facilities to computer programmers for software development. An *IDE* normally consists of a source code editor, build automation tools and a debugger. Arduino is an open-source prototype platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on a LED, publishing something online. All this is defined by a set of instructions programmed through the Arduino software (IDE). The software of Arduino platform is the Arduino Integrated Development Environment (IDE). The first step in the IDE checks whether the C or C++ code is correct. After checking whether the code is correct, the IDE passes the code to a compiler (avr-gcc) to change it from human readable to machine readable instructions. Then, the code is combined with the Arduino libraries code, which provides a basic function. The result of this process is a single hex file. This file contains the specific bytes and it is ready to write to the program memory on the Arduino board, which is transmitted to the Arduino over a USB port or serial connection.

a) Downloading the software

The Arduino is programmed using an open source application that runs on your computer. This is known as the IDE (integrated development environment) and can download it for free directly from the Arduino website's software area. The Arduino development environment contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It connects the Arduino hardware to upload programs and communicate with them. This software comes with the Arduino or can be

downloaded at no cost from the Arduino site. It is built in Java. With this software, we can edit, write sketches and upload code to the Arduino. The basis of this software is the C- language. The software is set up in the computer. The compiler is open source.

b) Using an arduino IDE

The Arduino IDE is splited into three areas. The blue area at the top of the window features a toolbar of buttons that control program behaviour. The white area in the middle is where you enter and modify the code. The black section at the bottom of the window is where status messages appear, and should look for error messages that can help to debug the code.

Software written using Arduino is called sketches, which are written in the text editor. Sketches are saved with the file extension .ino. It has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino environment including complete error messages and other information. The bottom right-hand corner of the window displays the current board and serial port. The toolbar buttons perform the following functions:

Verify/Compile	Checks your code for errors.
Stop	Stops the serial monitor or removes the highlight from other buttons.
New	Creates a new sketch (what Arduino programmers call their programs).
Open	Presents a menu of all the sketches in your sketchbook (the Arduino program directory). Clicking one will open it within the current window.
Save	Saves your sketch.
Upload to I/O Board	Compiles your code and uploads it to the Arduino board.
Serial Monitor	Opens the serial monitor.

Additional commands are found within the five menus: File, Edit, Sketch, Tools and Help. The menus are context sensitive which means, only those items relevant to the work currently being carried out are available.

3.2.2 The LabVIEW

LabVIEW is a graphical development environment for mounting convention applications. The tools available in LabVIEW make it more users friendly. Any non-programmer can do the LabVIEW programming easily using drag and drop system. The figure 3.1 shows the different components accessible in LabVIEW [9].

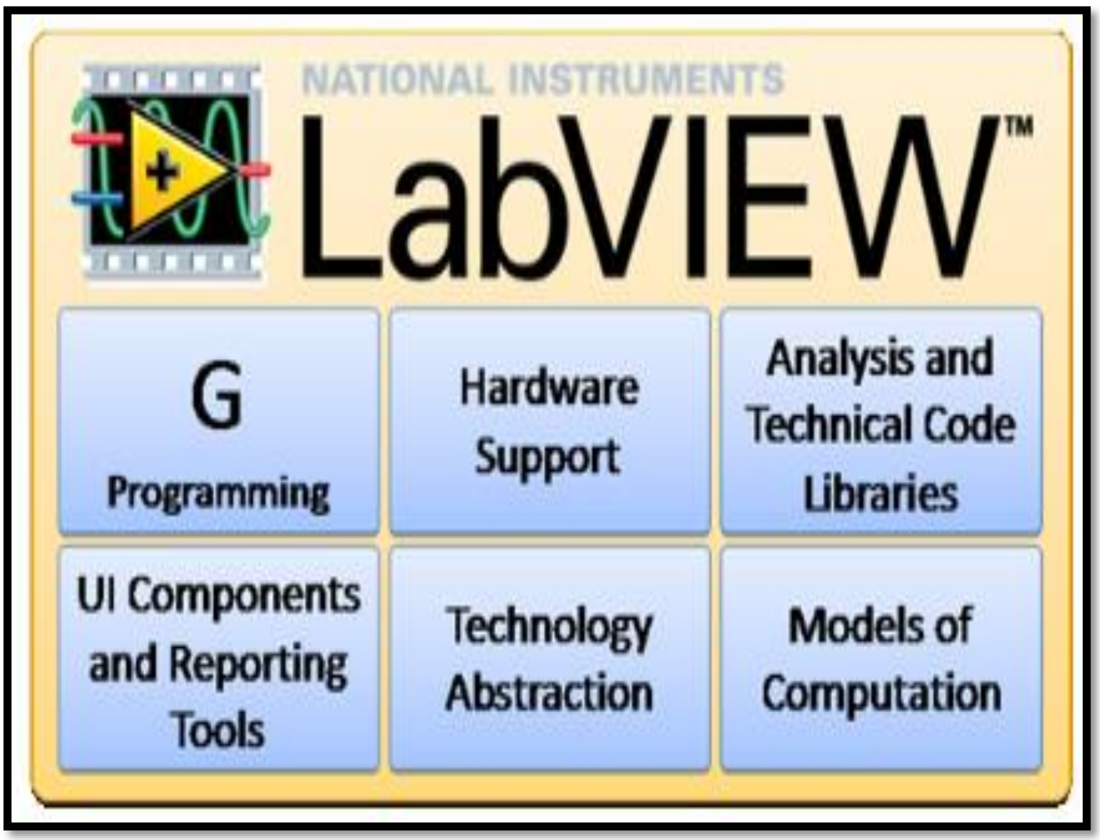


Fig.3.1. LabVIEW different components.

a) G - code

The G code is the heart of LabVIEW programming. The statistics gaining and it's examination is possible through this tool. The programming flow is visible as we want using it. The compiler in it examines our code to effectual machine

code, which makes it unique [9]. The G-code created by LabVIEW is more perceptive to use than other programming languages [10]. A reduced amount of time is required to run the G-code.

b) Hardware compatibility with LabVIEW

It hold up for number of devices in concert with data acquirement, signal conditioning devices, equipment control device (such as GPIB, PXI) etc. The freeware obtainable drivers for different types of hardware's make the LabVIEW most intuitive [11]. The driverless hardware can be used low -level communication device.

c) The tools in LabVIEW

LabVIEW possess different types of tools to make the system interactive [12]. The tools in the LabVIEW such as programming, instrument I/O, signal processing, mathematics etc. have its own function to create G-code regarding to this. Many of the controls like modern, classic, express used to create facile and effective GUI. LabVIEW has graphical palettes to create and run VI's. Any complex programming can be done easily using the tools available in this software. The present wireless gas sensing system uses the web publishing tool in LabVIEW to display the monitored data on the web page for remote monitoring.

d) Technology concept in LabVIEW

If we want to create a multifunction code for carrying out on multicore processors, can be done using NI's LabVIEW tool [12]. Without knowing this multi-threaded language, anyone can do this programming using tools existing in LabVIEW. The equivalent applies to new operating system also.

e) Mathematical functions

- ❖ With LabVIEW, any mathematical problem can be solved speedily without doing complex matrix and calculations.
- ❖ The formula node perform mathematical operations using formulae in our code
- ❖ The math script tool used to write functions and script in mathematical programming. Its syntax is similar to MATLAB.
- ❖ Simulation diagrams are helpful for real time monitoring and controlling.
- ❖ The strip chart shows tracing similar to oscilloscope.

These calculation models allow selection of the proper tool for the exacting crisis.

3.3 X-CTU Software

X-CTU software is needed to run the programming with ZigBee. X-CTU is designed to function with all Windows-based computers running Microsoft Windows 98 SE and above. This program was designed to interact with the firmware files found on Digi's RF products and to provide a simple-to-use graphical user interface to them. When launched, four tabs across the top of the program can be seen. Each of these tabs has a different function.

3.3.1 Programming with the ZigBee for wireless gas sensing system

The present wireless gas sensing system consists of a total of five sensor nodes. Out of these four sensor nodes are configured as routers and one is configured as co-ordinator. As shown in fig.3.6, the modem configuration window should be selected for programming the ZigBee. While programming, as stated above, the default setting of the devices should be read. Before beginning with the configuration, the device must be selected. Here, the device XB24-ZB is selected. Then, the function for which the device is to be programmed is selected. The X-CTU windows for configuration of ZigBee devices as router are shown in fig.3.2, whereas X-CTU windows for configuration of ZigBee as co-ordinator are shown

in fig.3.3. The table 3.1 shows various parameters for ZigBee device as router, whereas, table 3.2 cites parameters for configuration of ZigBee device as co-ordinator. The details regarding the parameters and it's configurations are as under.

The 802.15.4 RF protocol uses addressing to distinguish one radio from the next and prevents duplicate data packets. It is very important that each of the XBee modules have an unique source address (MY) to prevent non duplicate messages from being ignored as duplicates. Every XBee radio has a 64-bit serial number address printed on the back .The higher part of the address will be the same for every radio, while lower part of the address will be different for every radio. The 802.15.4 specification has two basic forms of addressing between the modules, Broadcast and Unicast. A Broadcast message is a message that will be received by all modules on any given PAN (by default Digi uses the PAN ID=0x3332). In 802.15.4, a Broadcast message is sent only once and not repeated, hence there is no guarantee of any given node receiving the message. A Unicast message is a more reliable method for delivering data. A Unicast message is sent from one module to any other module based on the module's addressing. This greatly increases the probability of getting the data through to the destination.

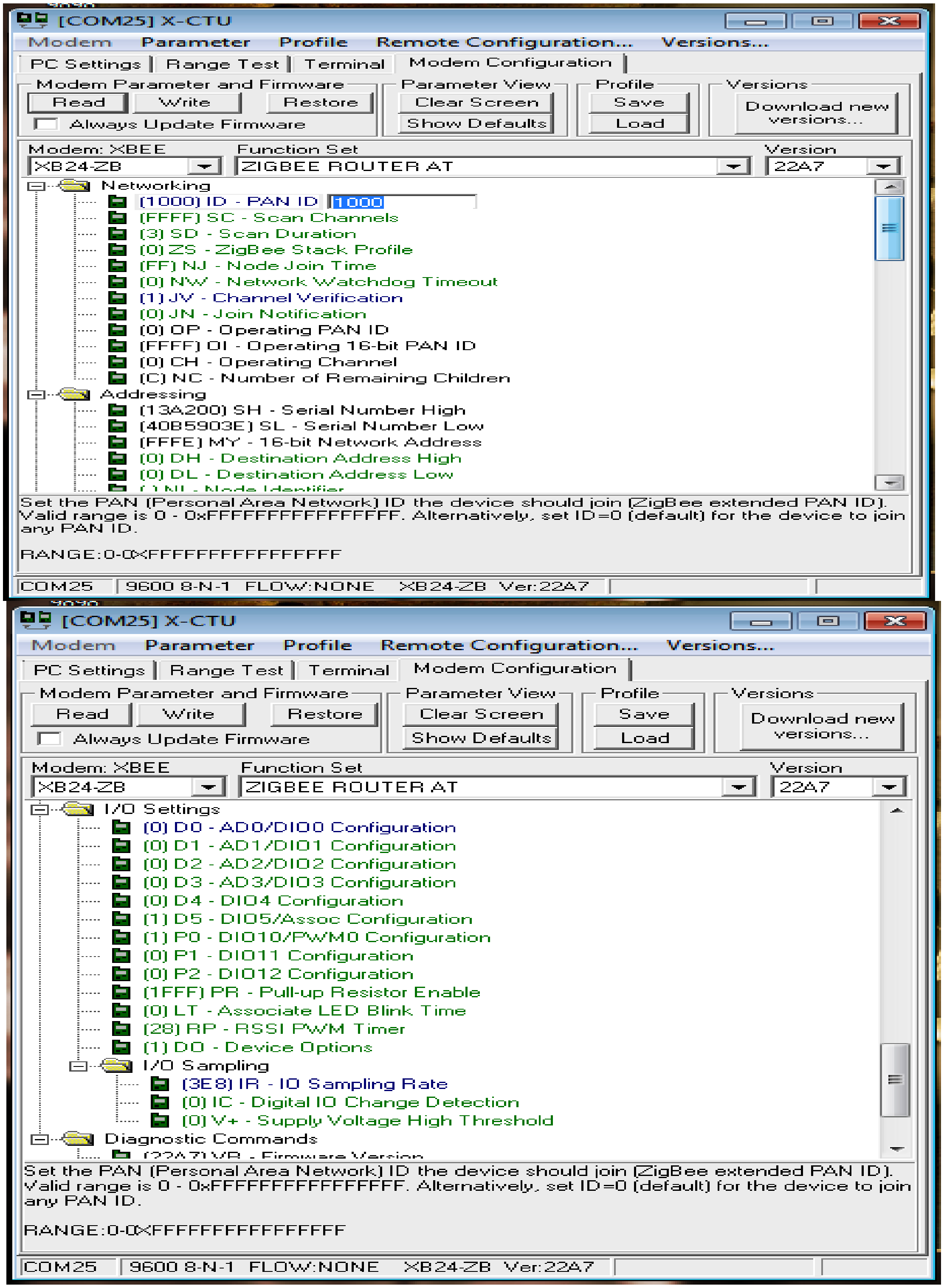


Fig.3.2 X-CTU windows for configuration of ZigBee devices as router.

The ZigBee programming for router is done as follows.

Sr. No.	Parameters Name	Parameters Symbol	Configuration Value
1.	PAN ID	ID	1000
2.	Destination address High	DH	0
3.	Destination address Low	DL	0
4.	Scan Channel	SC	FFFF
5.	Scan Duration	SD	3
6.	Channel Verifications	JV	1
7.	Device Option	D0	1
8.	Node Identifier	NI	Node 1 to Node 4
9.	Node Join Time	NJ	FF
10	Node Discovery Back off	NT	3C
11	Power Level	PL	4
12	Power Mode	PM	1
13	Power at PL4	PP	3
14	Baud rate	BD	3
15	RSSI PWM Timer	RP	28
16	DI07 Configuration	DI07	1
17	DI06 Configuration	DI06	0
18	IO Sampling rate	IR	3E8
19	Parity	NB	0
20	RSSI of last packet	DB	0

Table 3.1- The parameter of ZigBee as a router.

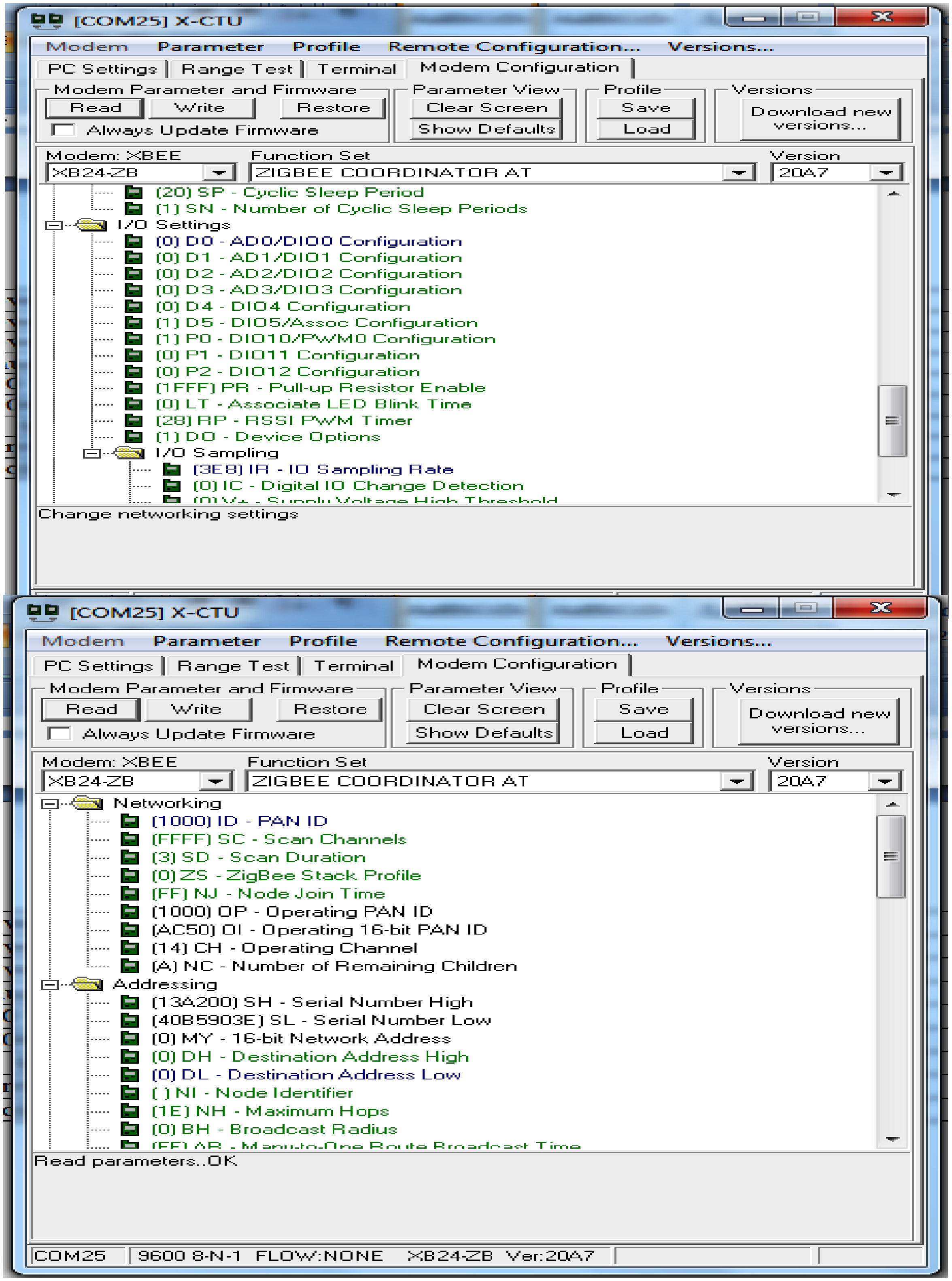


Fig.3.3. X-CTU windows for configuration of ZigBee devices as co-ordinator.

Sr. No.	Parameters Name	Parameters Symbol	Configuration Value
1.	PAN ID	ID	1000
2.	Destination address High	DH	0
3.	Destination address Low	DL	0
4.	Scan Channel	SC	FFFF
5.	Scan Duration	SD	3
6.	Channel Verifications	JV	0
7.	Device Option	D0	1
8.	Node Identifier	NI	--
9.	Node Join Time	NJ	FF
10.	Node Discovery Back off	NT	3C
11.	Power Level	PL	4
12.	Power Mode	PM	1
13.	Power at PL4	PP	3
14.	Baud rate	BD	3
15.	RSSI PWM Timer	RP	28
16.	DI07 Configuration	DI07	1
17.	DI06 Configuration	DI06	0
18.	IO Sampling rate	IR	3E8
19.	Parity	NB	0
20.	RSSI of last packet	DB	0

Table 3.2- The ZigBee parameters for device configuration as co-ordinator.

3.3.2 AT communication modes

The AT-configured radio can be used in two modes:

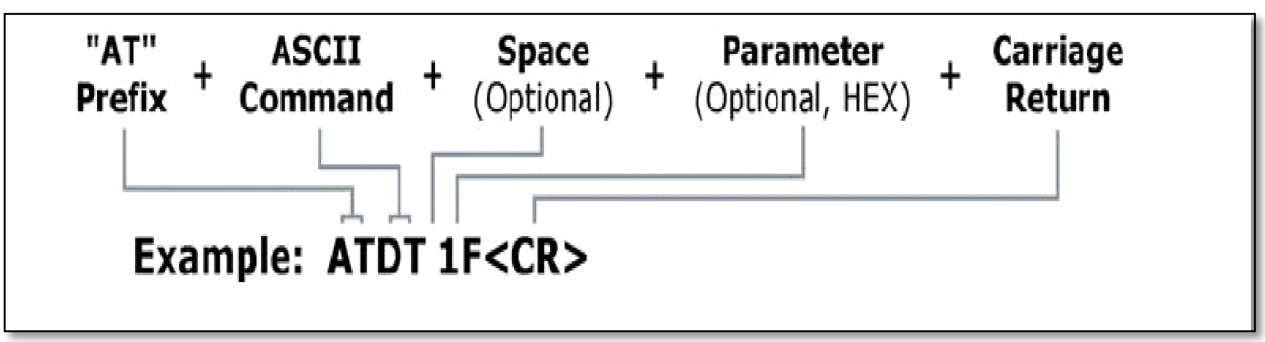
a) Transparent mode: This mode allows simple serial transmission and reception of one XBee with remote node. This mode is called transparent because of the transparent protocol link between two nodes to the user.

b) Command mode: In this mode, the user talks to the radio rather than passing the data through it. AT commands are used by the user in order to configure XBee radio such as destination address, PAN (Personal Area Network) ID, sleep mode and sleep period. AT commands are a descendant of the Hayes command set that was originally developed for configuring telephone modems [13].

To enter into command mode, the following steps must be taken in order to inform the module that the received characters are commands and data to be sent:

• Three Characters "+++" are input to the module within one second.

Every command is followed by AT. For example, the command CH for choosing a channel frequency is written ATCH. The user can enter dedicated commands for his/her configuration of the module via terminal software or X-CTU software offered by Digi's. Regardless of the software used, the communication with XBee will be through the serial port. The syntax of sending AT command is shown as follows.



3.3.3 API communication mode

An Application Programming Interface (API) is simply a set of standard interfaces created to allow one software program to interact with another. They are

generally not designed for direct human interaction. In API mode, the programmer packages the data with necessary information, such as destination address, type of packet, and checksum value. Also, the receiving node accepts the data with information such as source address, type of packet, signal strength and checksum value. The advantages are that the user can build a packet that includes important data, such as destination address and that the receiving node can pull from the packet information such as source address of the data. While more programming intensive, API mode allows the user greater flexibility and increased reliability in some cases [14]. They use API mode to implement their operations such as:

- Addressing different nodes without entering the command mode.
- Automatic retries and acknowledgements of transmissions.
- Collision avoidance.
- Identification of the source address of each received packet.
- A checksum.

3.4. Flowchart for Wireless Gas Sensing System

This system focuses more on the study case and monitoring the wireless gas sensing system. The microcontroller will continuously receive the data from various sensor nodes. It will process the data and convert it into ppm. The converted data will be displayed on the web browser. Whenever the reading of the sensors exceeds the limit set, it will automatically send an SMS alert wirelessly by using GSM network to the numbers as being set on the source code. The project methodology shows the step by step taken in order to complete this wireless gas sensing system and includes the planning, the development of the design and the management of the system.

3.5 Software Implementation

This section will specifically discuss the methodology to interface the sensor and hardware module. The most important part is to enable the analog sensor to send the analog data to arduino and then transfer to the LabVIEW.

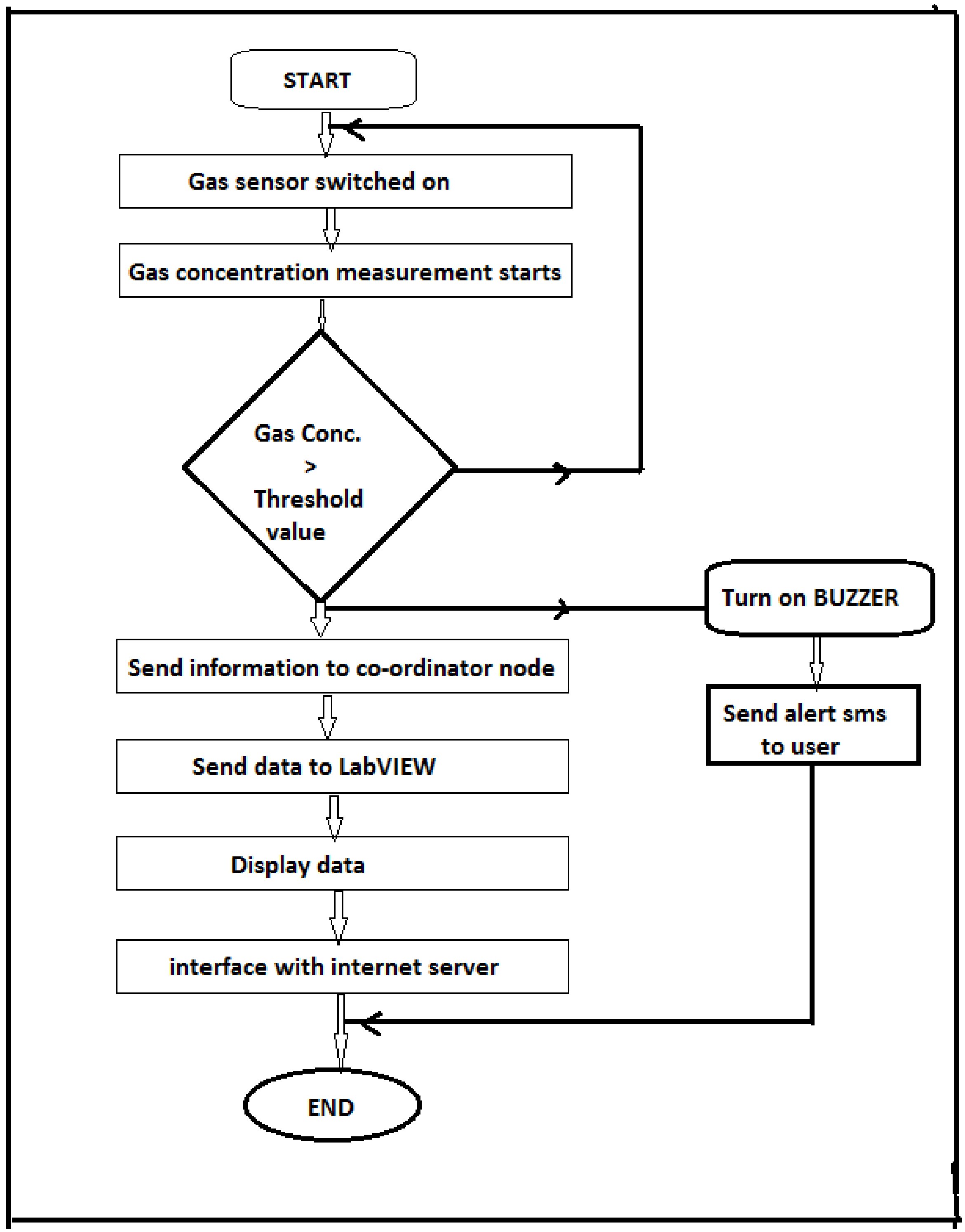


Fig.3.4. Flowchart of the wireless gas sensing system.

The gas concentration calculation process is explained in details in the following section. The required arduino programming and LabVIEW programming for

monitoring of the gas leakage and web browsing programming are described below.

3.5.1 Gas concentration calculation

Based on the datasheet of MQ-2, the input and output voltage range is as follows:

Input voltage: DC 5.0 ± 0.2 V

Output voltage: DC 0 – 5.0 V.

An arduino is 10 bit analog to digital converter microcontroller. Therefore, based on the hardware, the real input voltage of gas sensor is 5V.

As arduino is 10-bit, it is equal to 2^{10}= 1024 steps or levels of the resolution. The maximum output from a gas sensor (5V) is then divided into 1024.

5/1024= 4.88 mV per resolution.

From the calculation above, 1-bit output is equal to 4.88mV in the real voltage output. Fig.3.5 below shows the relation between voltage output from a gas sensor and an arduino reading more clearly.

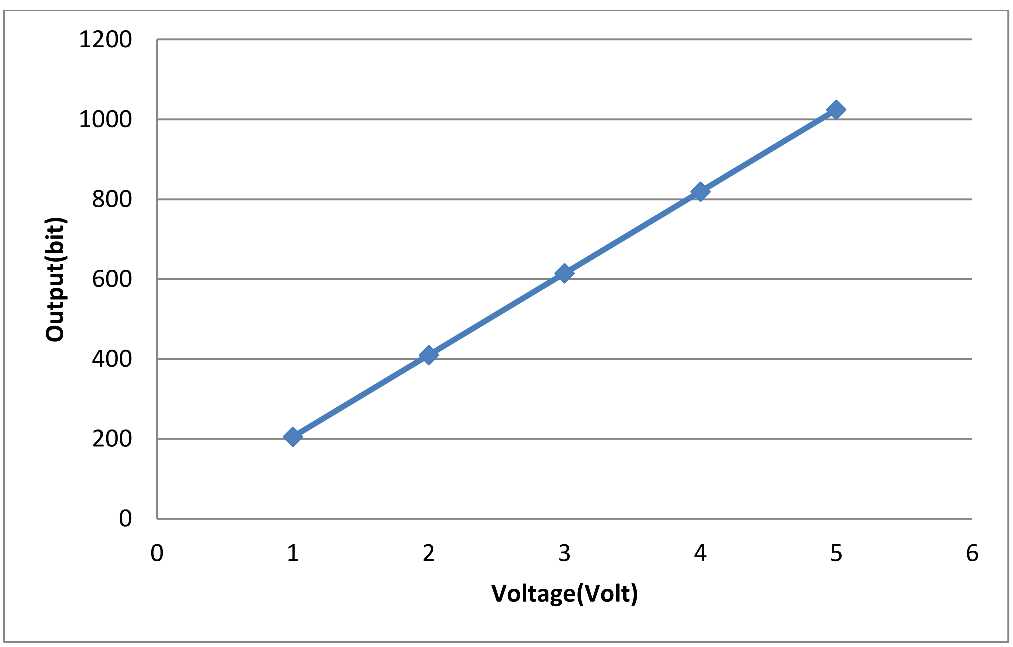


Fig.3.5. Output voltage of gas sensor Vs digital output in arduino.

As discussed in chapter 2, the gas concentration can be calculated using:

Gas Concentration = $\frac{10^6}{Volume\ of\ gas\ chamber\ (250\ cc)} x\ Volume\ of\ gas\ inserted$.. (1)

Since arduino only reads in the 10-bit numbering, concentration value need to convert into 10- bit data to program the arduino programmer. By using the above equation 1, value of the gas concentration can be obtained. The calculation for converting the value of voltage output (Vo) to digital output is based on the following equation;

Digital output = $\frac{Vo}{5}$ x 1024 ……. (2)

3.5.2 Arduino programming

The arduino programming is the heart of this system. This is because; all the data from sensor to LabVIEW monitoring system and alarm system are controlled by the arduino. Besides this, an arduino also triggers alarm system when threshold is detected that sets up and alert the peoples by sending SMS on their mobile. Moreover, an arduino sends the data to the computer in LabVIEW wirelessly with the ZigBee device.

a) The arduino programming for gas sensor

In this wireless gas leak detection system, the sensor is connected to an analog port of the Arduino nano board (sensor nodes), which measures various gas concentrations at ppm level and sends them to the Arduino UNO board (Gateway Node).The status of the sensor nodes where the leakage exists is shown in serial monitor window in a gateway node as below (fig.3.6). First, all the input and output pins in arduino must be declared. Then, initial sensor value must be set to 0. The data received from sensor can be converted into the decimal place as the float sensor declared below. The analog input pin that the potentiometer of gas sensor is attached to pin A0. The declaration programme for this step is shown below.

```
Const int analogInPin = A0;
int buz=13;
int sensorValue = 0;
```

float voltage;

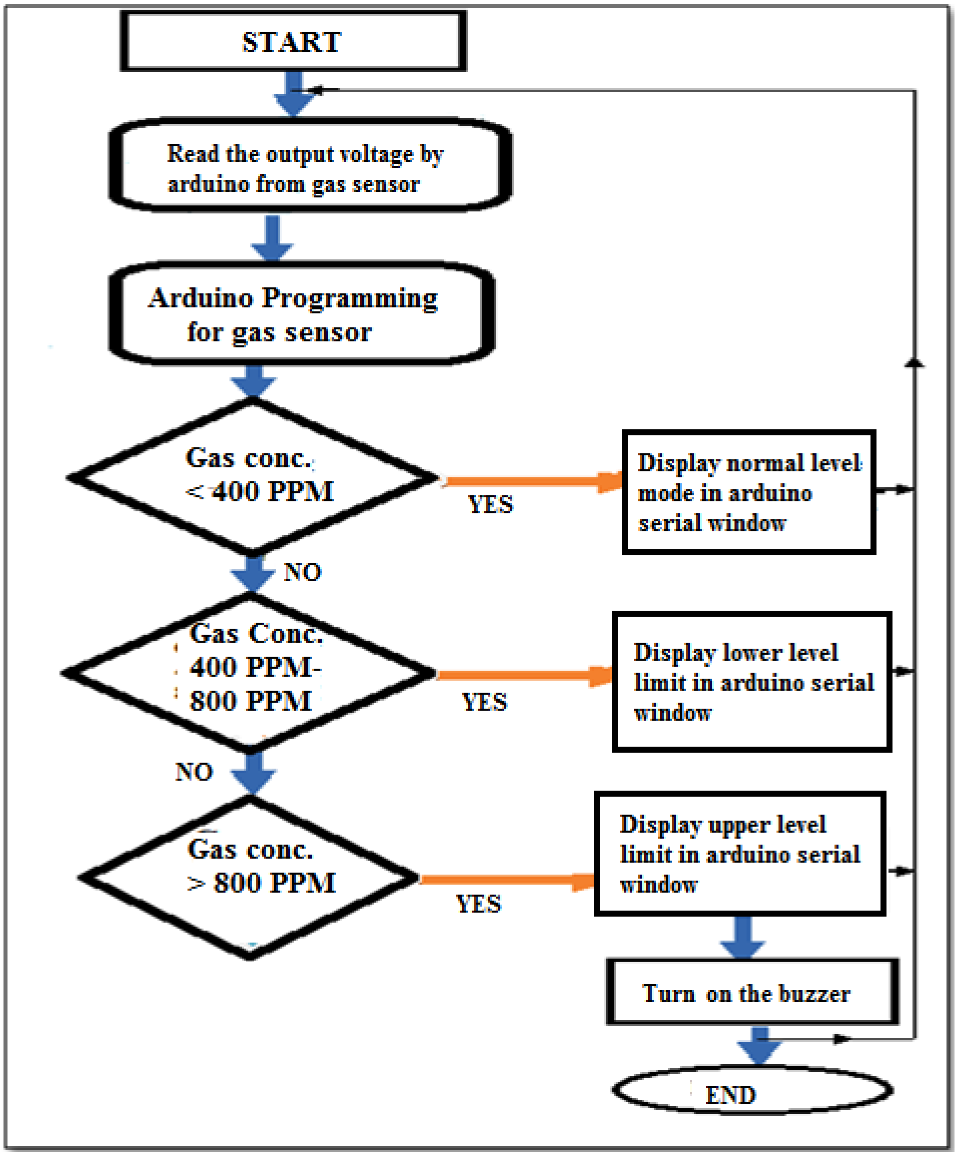


Fig. 3.6. Flowchart of arduino programming for LP gas sensor.

After that, loop is very important which represents all the data that repeat continuously with time. In this system, there are two loops are included. First loop is to initiate serial communication at the baud rate of 9600. This sets the digital pin as the output as shown below.

void setup()

{

Serial. begin (9600);

}

The second loop is mostly the main process for the alarm system trigger. All the threshold value is declared in this loop. First of all, the system reads the sensor value as shown in Figure 3.7(a). If the sensor value is over or under the limitation of the threshold values, the output system will be turned on. Finally, the result from the sensor value is printed to the serial monitor shown in fig.3.7(b).

```
Void loop ()
{
int sensorValue = analogRead(A0);  // read the input on analog pin 0:
  // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
float voltage = sensor Value * (5.0 / 1023.0);
Serial.println(voltage);     // print out the value you read:
if (voltage <=1.5  )
{
//"gas detected" message will be displayed in serial monitor
  Serial.println ("   LPG DETECTED in normal level mode.");
delay (1000);
}
if (voltage >=1.5&& voltage <=4.2)
{
//"gas detected" message will be displayed in serial monitor
Serial.println (“LPG DETECTED in lower level limit.");
delay(1000);
}
if (voltage >=4.2)
{
//"gas detected" message will be displayed in serial monitor
   Serial.print (“LPG DETECTED in upper level limit.");
```

```
  Serial.println (Explosive level of gas leakage.");
delay(1000);
}
else
{
Serial.println("  no gas leakage");
delay(1000);
}
}
```

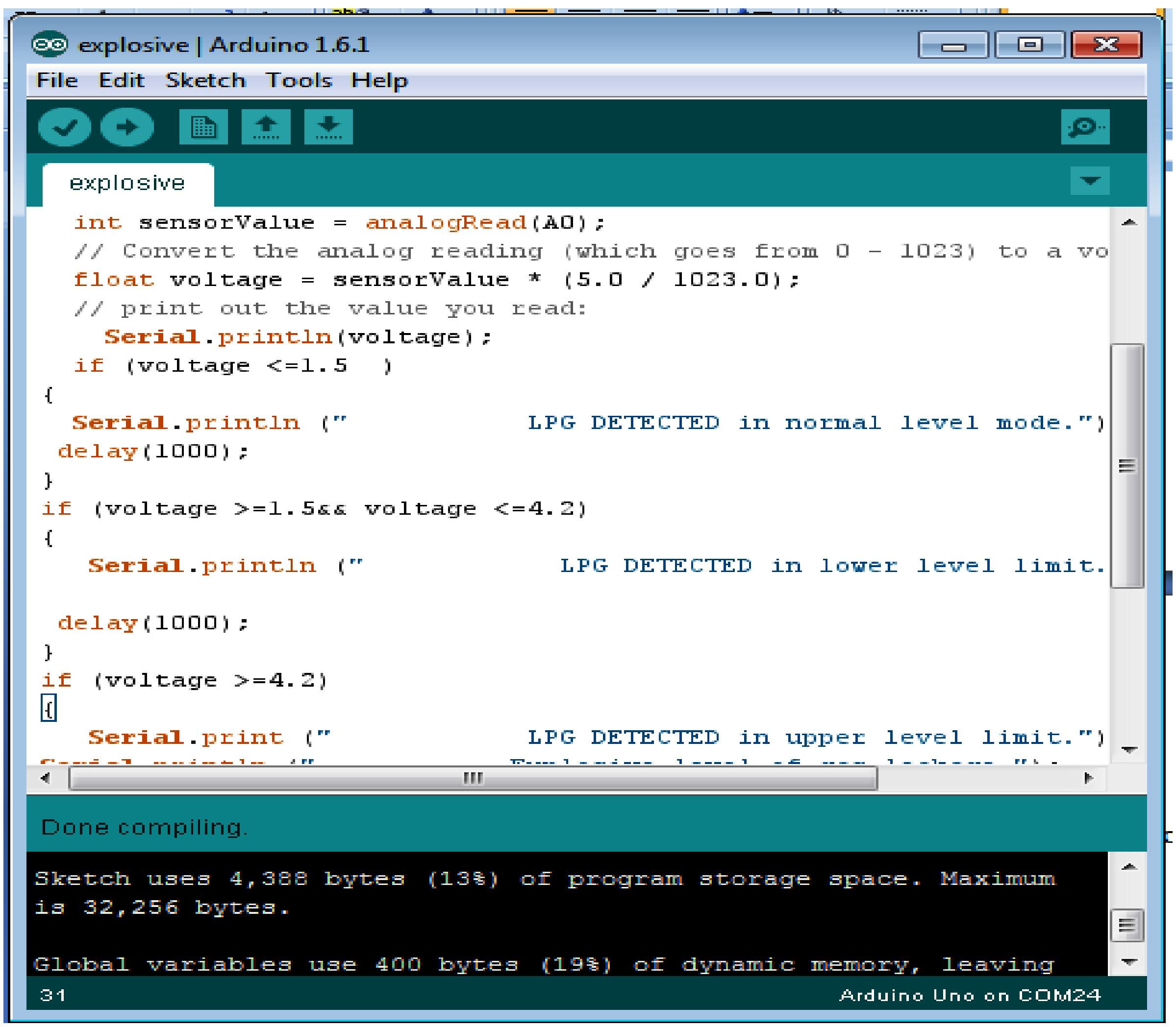


Fig. 3.7. a) Programming process in arduino.

```
Sensor Node1      no gas leakage
0.00
Sensor Node2             no gas leakage
0.03
Sensor Node1      no gas leakage
0.00
Sensor Node2             no gas leakage
 1.05
Sensor Node1            LPG DETECTED, gas conceration is 200 ppm.
0.00
Sensor Node2             no gas leakage
1.05
Sensor Node1            LPG DETECTED, gas conceration is 200 ppm.
0.00
Sensor Node2             no gas leakage
0.00
Sensor Node1      no gas leakage
0.00
Sensor Node2             no gas leakage
·1.05
Sensor Node1            LPG DETECTED, gas conceration is 200 ppm.
0.00
Sensor Node2             no gas leakage
```

Fig.3.7.b) Arduino programming for the sensor value.

b) Arduino programming for GSM shield

The shield uses a radio modem M10 by Quectel and it is possible to communicate with the board using AT commands. The shield establishes for software serial communication with the M10. Pin 2 is connected to the M10's TX pin and pin 3 to its RX pin. The modem's PWRKEY pin is connected to Arduino pin 7. The M10 is a Quad-band GSM/GPRS modem that works at frequencies typically, at GSM 850MHz, GSM 900MHz, DCS 1800MHz and PCS 1900MHz. It supports TCP/UDP and HTTP protocols through a GPRS connection. GPRS data downlink and uplink, transfer maximum speed is 85.6 kbps. The modem can pull up to 2A of current at peak usage, which can occur during data transmission. This current is provided through the capacitor on the board [15-17].

The arduino programming for sending the SMS to the user after gas leakage detection is done as follows.

Program:

 * GSM shield

* SIM card that can send SMS

```
 Created 25 Feb 2014 by Mujawar T.H */
// include the GSM library
#include <GSM.h>
#define PINNUMBER " "
// initialize the library instance
GSM gsmAccess;
GSM_SMS sms;
int  time=1;
int count=0;
char phone_no[ ]= "xxxxxxxxxx";
char message[ ]="gas leakage,  Kind Attention";
void setup()
{
  // initialize serial communications and wait for port to open:
Serial.begin(9600);
while (!Serial)
 {
    ; // wait for serial port to connect.
}
  Serial.println("SMS Messages Sender");
// connection state
boolean notConnected = true;
  // Start GSM shield
  // If your SIM has PIN, pass it as a parameter of begin() in quotes
while (notConnected)
  {
if (gsmAccess.begin(PINNUMBER) == GSM_READY)
notConnected = false;
```

```
else
    {
Serial.println("Not connected");
delay(1000);
   }
  }
  Serial.println ("GSM initialized");
}
void loop()
{
while(count <time)
{
delay(1000);
Serial.println(phone_no);
  // sms text
Serial.print(message);
Serial.println("SENDING");
Serial.println();
Serial.println("Message:");
Serial.println(message);
  // send the message
sms.beginSMS(phone_no);
sms.print(message);
  sms.endSMS();
Serial.println("\nCOMPLETE!\n");
}
}
```

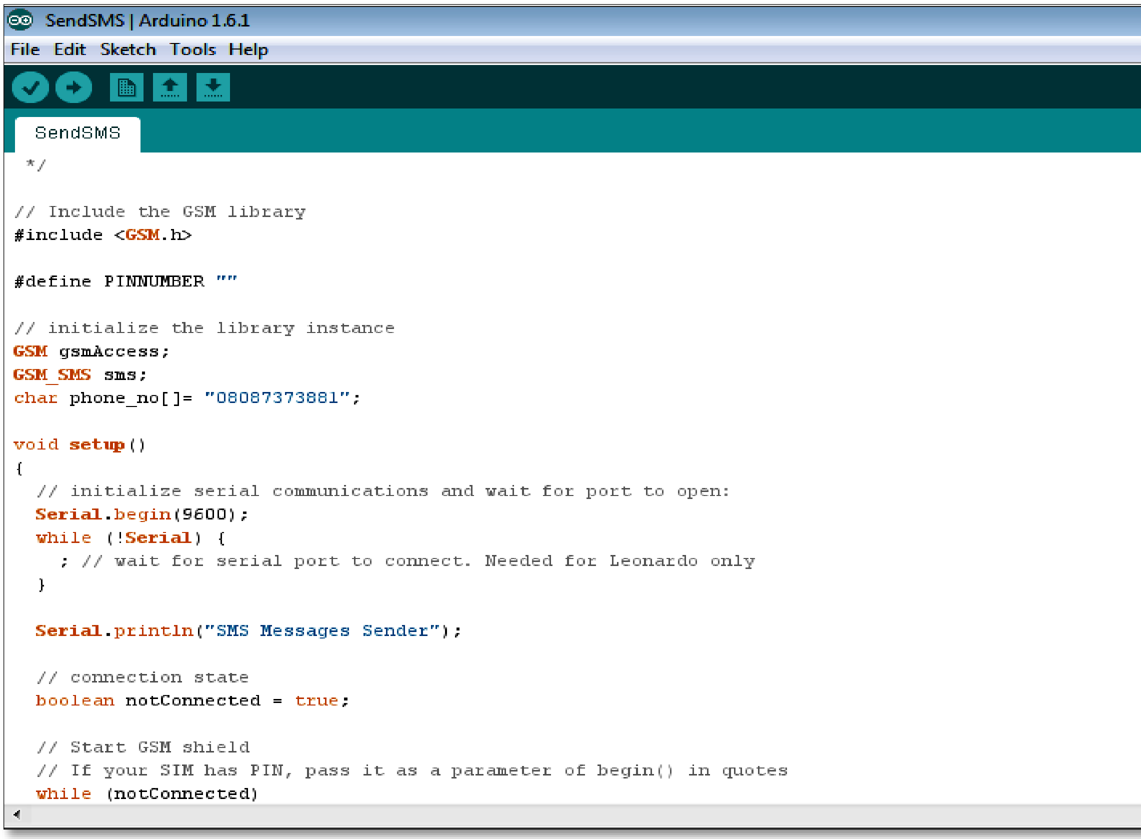


Fig. 3.8.Arduino GSM shield programming.

In order to perform the correct operation of the proposed system, we selected a fixed phone number in our system and applied different operations (monitoring). The user is from the different locations than the gas leakage place [18]. Fig.3.9 shows the pictures taken from the user's mobile phone after the fixed phone number in GSM shield sends SMS when gas leakage happens. The mobile phones do not require to have any special applications or hardware to be used in this system and any mobile phone supporting the SMS service can be used in the system. At normal situation, just one mobile phone number can defend to send/receive command-messages in the system (i.e. home owner's phone number). But, to add additional numbers, it can be done very easily by changing the related source code. We can change the message also by performing change in the program. If the gas concentration is above 800 ppm, the system sends an alert

message to the user. The message send to the user “gas leakage in explosive level”, is as follows (fig.3.10).

Fig.3.9. SMS indication on user mobile phone.

Fig. 3.10.SMS indication of explosive level of gas leakage.

3.5.3 The programming for wireless access

For the present WSN sensor node, the RF section is designed with ZigBee devices. To ensure wireless communication, the ZigBee is interfaced to microcontroller in Universal Asynchronous Receiver Transmitter (UART) mode shown in (fig.3.11 and fig.3.12). Each ZigBee is programmed with respective node ID and establishes the communication with the co-ordinator. Both of the ZigBee receiver and transmitter must be set up with the programming in order to transfer data from Arduino successfully. Then, XCTU software is needed to run the programming with ZigBee. Once the XCTU software is installed and executed in the computer, each COM for each ZigBee must be tested by clicking on the button, Test/Query (fig.3.17).

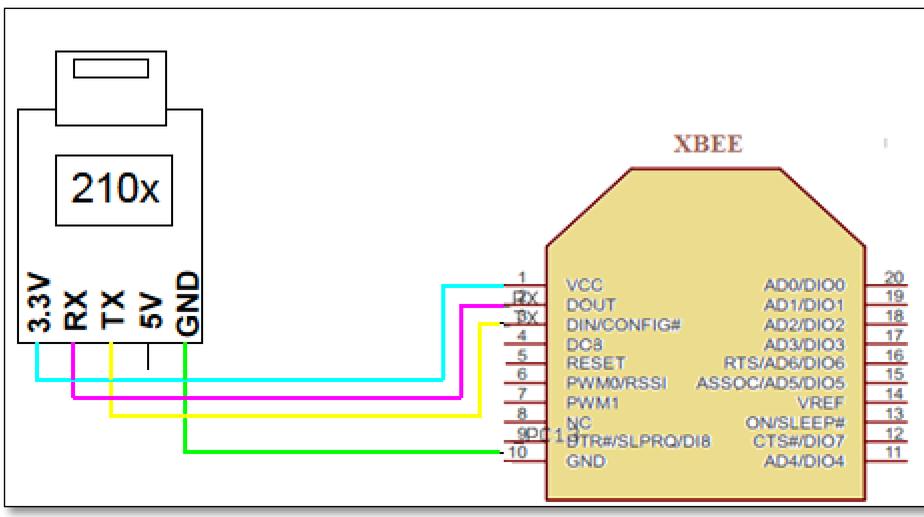


Fig. 3.11.XBee connection to USB port.

X-CTU software is supported for programming and configuring ZigBee, WIFI modules. A dialog box was popped up to inform that the COM connection is successful [19-20]. Figure 3.13 shows the result output for Com test. The set up for the ZigBee data transfer is done by opening the modem configuration at the upper right corner of the window X-CTU (fig.3.13). This step is very important to make sure that the data has been transferred to the exact location. There were four items that need to be considered. First is PAN ID. This is to show the location

number of the port. The value of the ID must be the same.

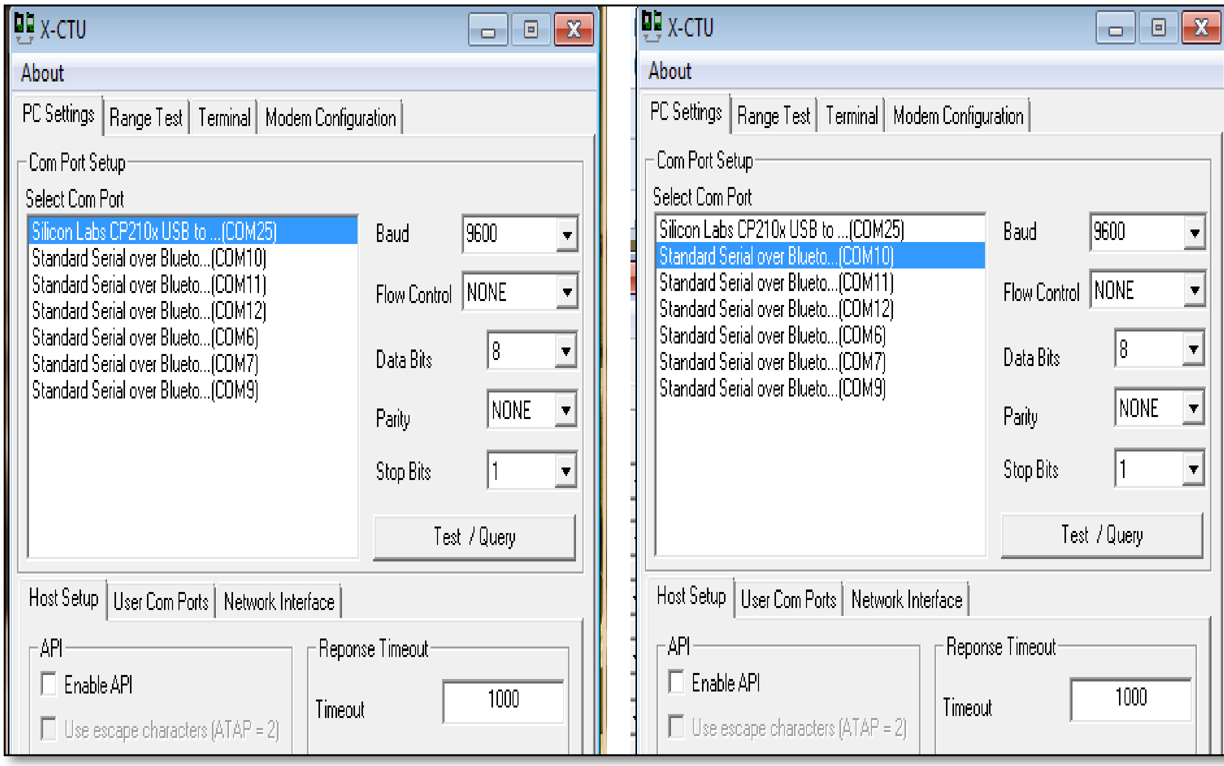


Fig. 3.12. COM port testing of ZigBee.

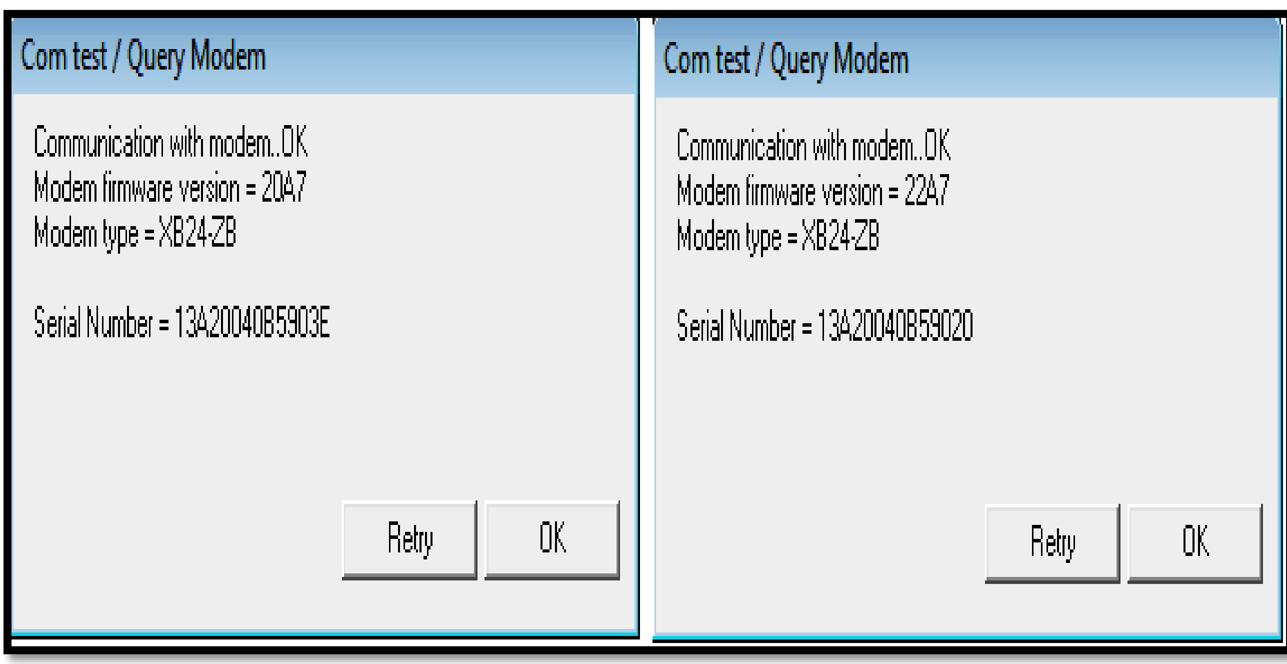


Fig. 3.13. Result output for Com Test.

The ID for this ZigBee is 1000. Then set the destination address high as 1 and the destination address low as 0. Serial interfacing is the most important things, we set the baud rate at the arduino at 9600 and the interfacing data rate also must be 9600. Figure 3.14 shows the serial interfacing data rate at 3 which is equal to 9600.

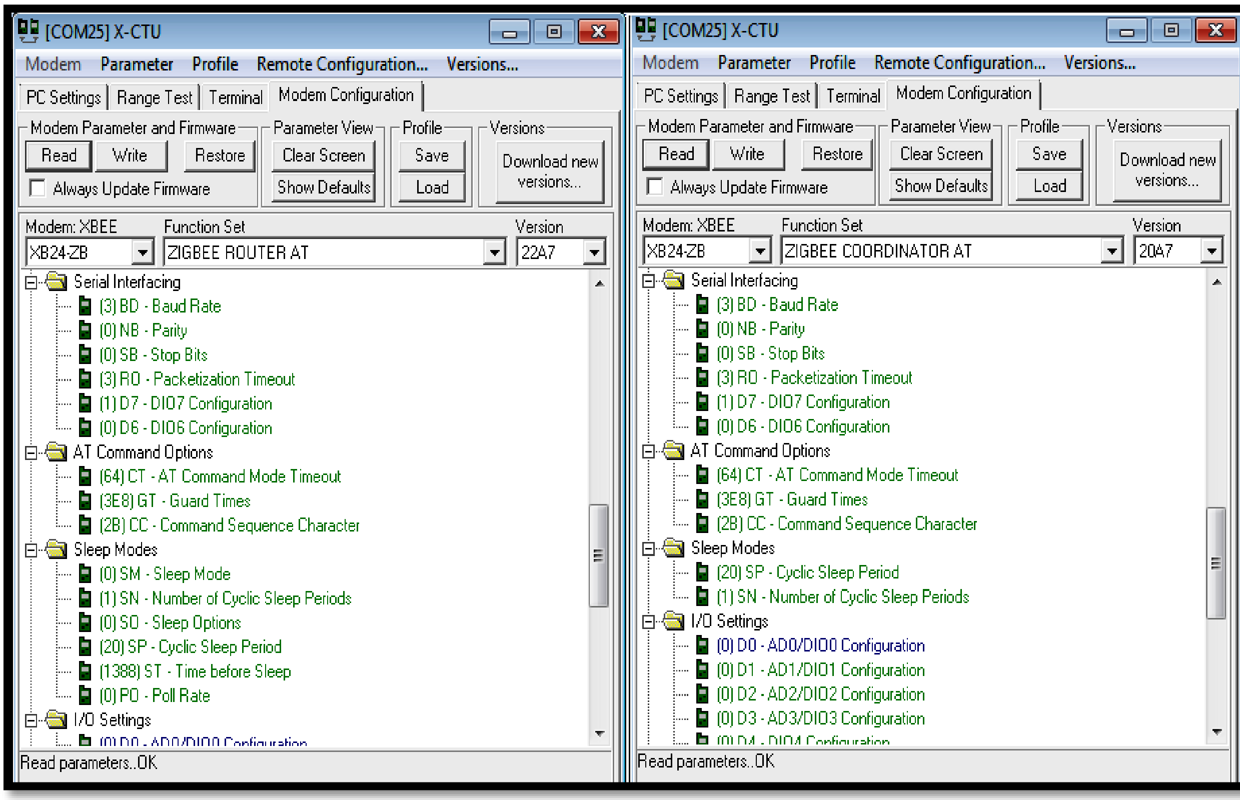


Fig. 3.14. Serial interfacing.

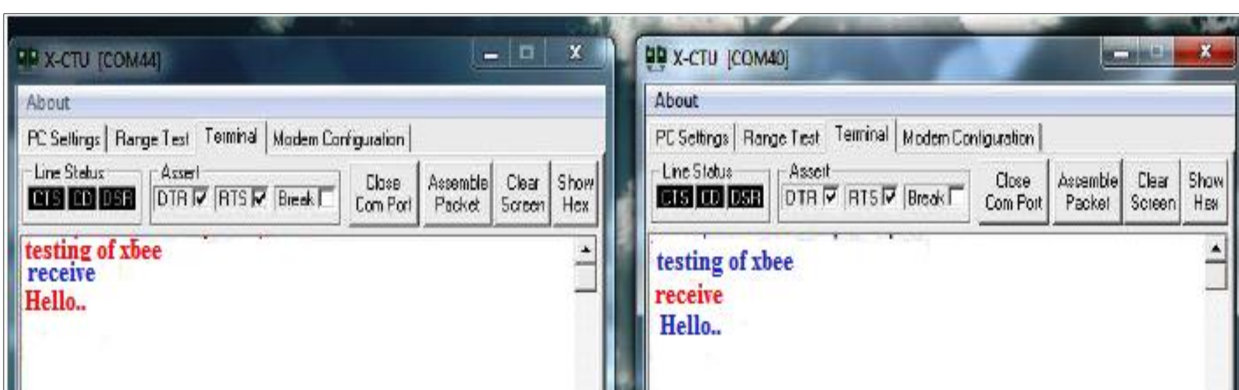


Fig. 3.15. Data transfer between two ZigBee's.

The last step is to test the connection between two ZigBee's. Figure 3.15 shows the successful data transfer between two ZigBee's. As shown in figure 3.15, writing in blue colour is the data transfer at COM 25. Meanwhile, the red colour in COM10 is the receiver and vice versa. Therefore, both the ZigBee's can be used as the receiver and transmitter terminals.

3.5.4 Star topology implementation

The ZigBee was used in star topology that makes all the devices attached to a central control unit (fig.3.16). The range of ZigBee network was increased using multiple routers. The use of ZigBee module has complexity in identifying the nodes connection however, in case of any breakdown; it finds an alternate route to execute the command without affecting itself. Arduino programming for router and coordinator was done and is shown in fig.3.17.

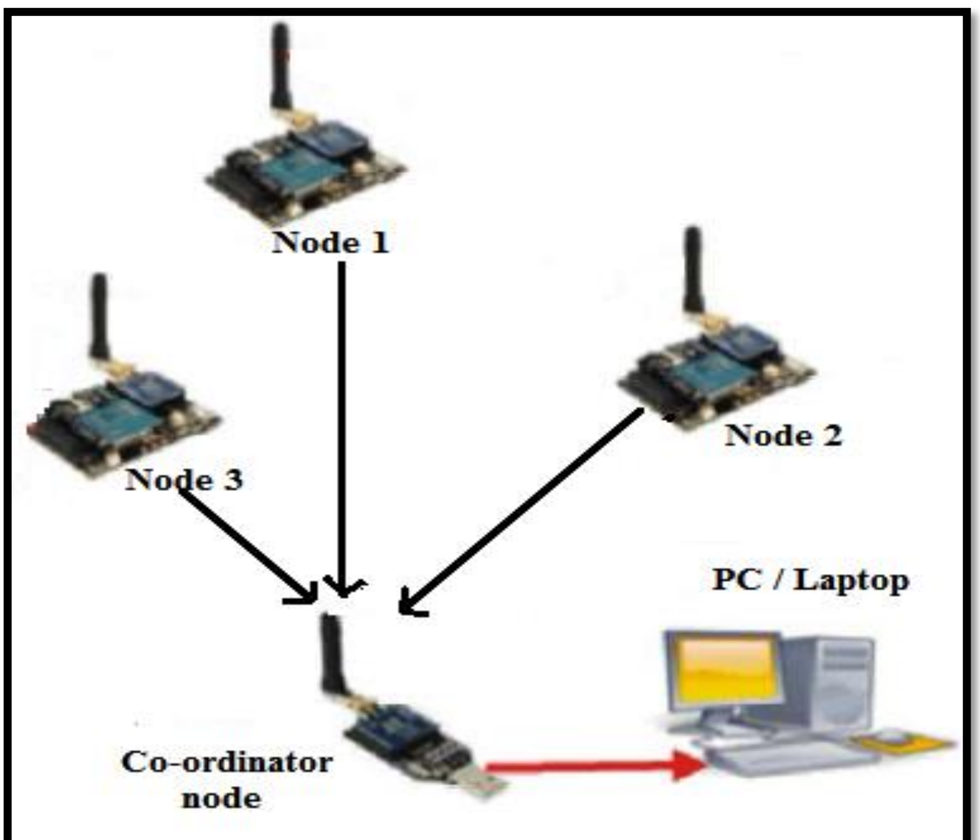


Fig. 3.16. Star topology implementation of ZigBee.

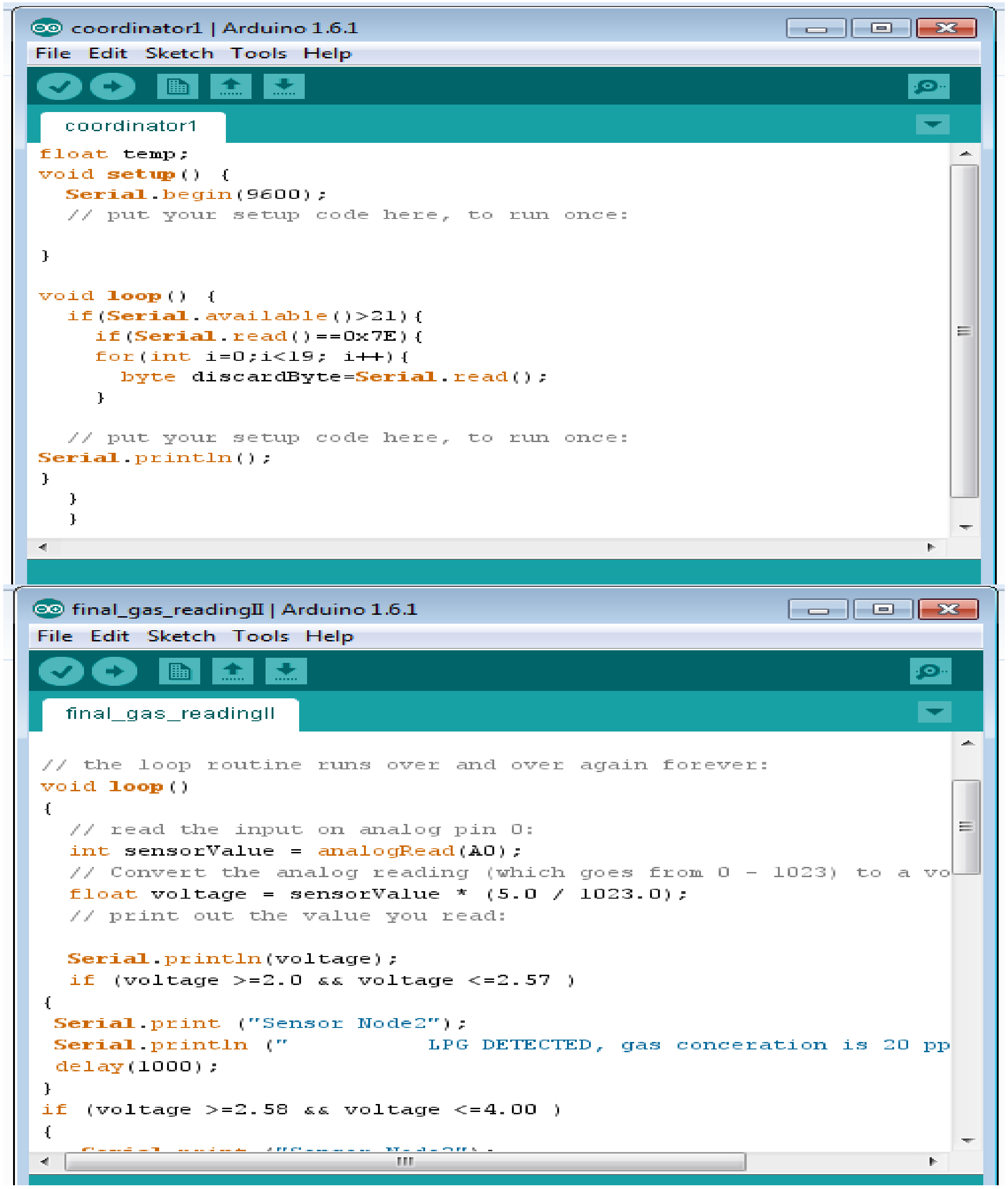


Fig. 3.17. Arduino programming for star topology implementation.

3.6 Alert Systems

Liquid petroleum gas (LPG) is a mixture of propane and butane which is highly flammable chemical. It is versatile in nature and hence used for many applications such as in heating, domestic and industrial purposes and automobile fuels. LPG is used in many vehicles because of its desirable properties which include high calorific value and produce less smoke. Another widely used fuel in

the home is the natural gas. Leakage of these gases in the air is the serious problem. The gases being heavier than air do not disperse easily and it may lead to suffocation when inhaled [21]. The gas leakage in the air causes explosion. The natural gas and LPG burn produce clean energy but there is a serious problem about their leakage. In recent years due to explosion of LPG, numbers of accidents have been increased. Hence, Gas leakage detection and it's alerting is equally important. The leakage of gas alerts in many ways. The proposed system alerts the leakage of gas by two ways:

a) Sending SMS to the user
b) BUZZER.

a) SMS on user mobile phone

When the system detects the LPG concentration in the air that exceeds the certain level, it immediately alerts the persons by activating an alarm and sending message to the specified mobile phone. The proposed system uses the GSM to alert the person about gas leakage via SMS.

An alert message is sent through the GSM [22] to the user and a buzzer alarm is activated in the room. This alarm produces huge sound which drops down the attention of user and neighbours in current leak/fire accidents. This is done by using arduino GSM shield. This GSM shield is embedded on Arduino controller board that reads the information (data) from sensor, process it and sends an SMS to the user. The GSM shield sends the message through AT commands. When the gas leakage is detected by the gas sensor, microcontroller sends a signal to GSM module in which one of the tasks is to send the text SMS as well as the call. GSM module requires one SIM card. This module is capable of accepting any network SIM card. Multiple users can be added to the SIM card.

b) BUZZER

An alarm is connected to a digital pin. Alarm indication alerts the peoples by providing the long beep. Instead of leaving voice alert, long beep has higher

frequency range that travels a long distance. The buzzer is connected to arduino pin 13 as shown in fig 3.18.

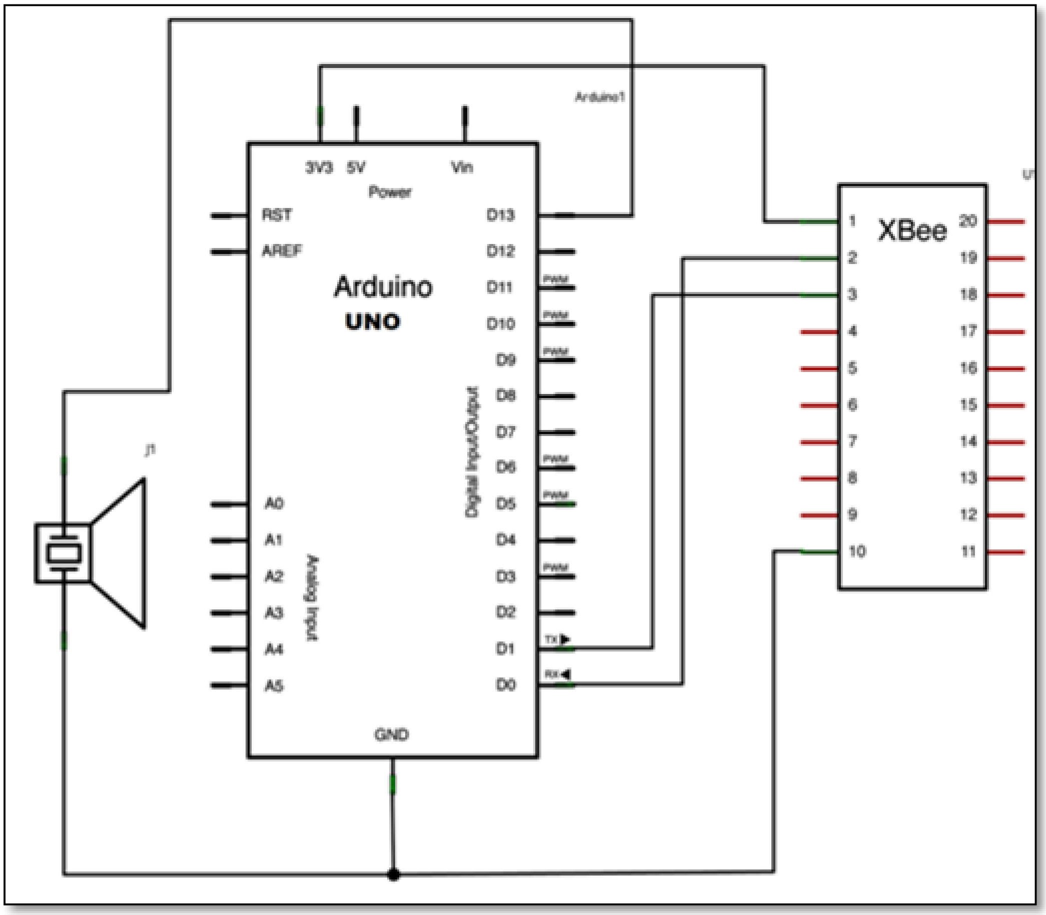


Fig.3.18.Buzzer connection to arduino board.

3.7 Main Program

The program for LPG gas leak detection monitoring and controlling is done as follows.

The program listing

****

****

//* Program created 25 Feb 2014 by Mujawar T.H */

```
**************************************************************
**********************************************************

#include <GSM.h>
#define PINNUMBER " "
GSM gsmAccess;
GSM_SMS sms;
int time=1;
int count=0;
constintanalogInPin = A0;
int buz=13;
int solenoidpin=11;
intfan=12;
intsensorValue = 0;
float voltage;
unsigned int interval = 100;
Char phone_no [ ] = "xxxxxxxxxx";
Char message [ ] ="gas leakage, Kind Attention";
void setup ()
{
// initialize the Sensor pin as an input:
   pinMode (sensorValue,INPUT);
// initialize the relay pin as an output:
pinMode (solenoidPin, OUTPUT);
   // initialize the fan pin as an output:
pinMode (FanPin, OUTPUT);
  While (! Serial)
 {
    ; // wait for serial port to connect.
```

```
}
  Serial.println("SMS Messages Sender");
// connection state
boolean notConnected = true;
  // Start GSM shield
  // If your SIM has PIN, pass it as a parameter of begin() in quotes
  While (notConnected)
  {
if (gsmAccess.begin(PINNUMBER) == GSM_READY)
notConnected = false;
else
    {
Serial.println("Not connected");
delay(1000);
   }
   }
  Serial.println ("GSM initialized");
Serial.begin(9600);
```

/* Calibration of sensor*/

```
   Void loop ()
{
int sensorValue = analogRead(A0);  // read the input on analog pin 0:
  // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
float voltage = sensor Value * (5.0 / 1023.0);
Serial.println(voltage);     // print out the value you read:
```

```
//*Normal level of gas leakage*//
if (voltage <=1.5  )
{
//"gas detected" message will be displayed in serial monitor
  Serial.println ("   LPG DETECTED in normal level mode.");
delay (1000);
}
```

```
//* Warning of gas leakage*//

if (voltage >=1.5&& voltage <=4.2)
{
//"gas detected" message will be displayed in serial monitor"//
   Serial.println ("LPG DETECTED in lower level limit.");
delay(1000);
}
*****************************************************************
// * Explosive level of gas leakage*//
if (voltage >=4.2)
    {
//"gas detected" message will be displayed in serial monitor"//
Serial. Print ("LPG DETECTED in upper level limit.");
Serial.println ("Explosive level of gas leakage.");
tone (buzzerPin,2500,interval); //Ring the buzzer when there is a gas leak detection
digital Write (solenoidPin, HIGH);// turn the solenoidPin on (HIGH is the voltage level)
  Serial.println (" Solenoid switch is pressed: close");
delay (2000);              // wait for a second
```

```
digital Write (solenoidPin, LOW);    // turn the Pin off by making the voltage
LOW
digital Write (FanPin, HIGH);   // turn the FanPin on (HIGH is the voltage level)
*******************************************************************
                                        //* Sending SMS to the user *//
While (count <time)
{
delay(1000);
Serial.println(phone_no);
  // sms text
Serial.print(message);
Serial.println("SENDING");
Serial.println();
Serial.println("Message:");
Serial.println(message);
  // send the message
sms.beginSMS(phone_no);
sms.print(message);
  sms.endSMS();
Serial.println("\nCOMPLETE!\n");
}
else

{
Serial.println("  no gas leakage");
delay(1000);
}
}
```

}

****

The arduino programming for these is done as follows.

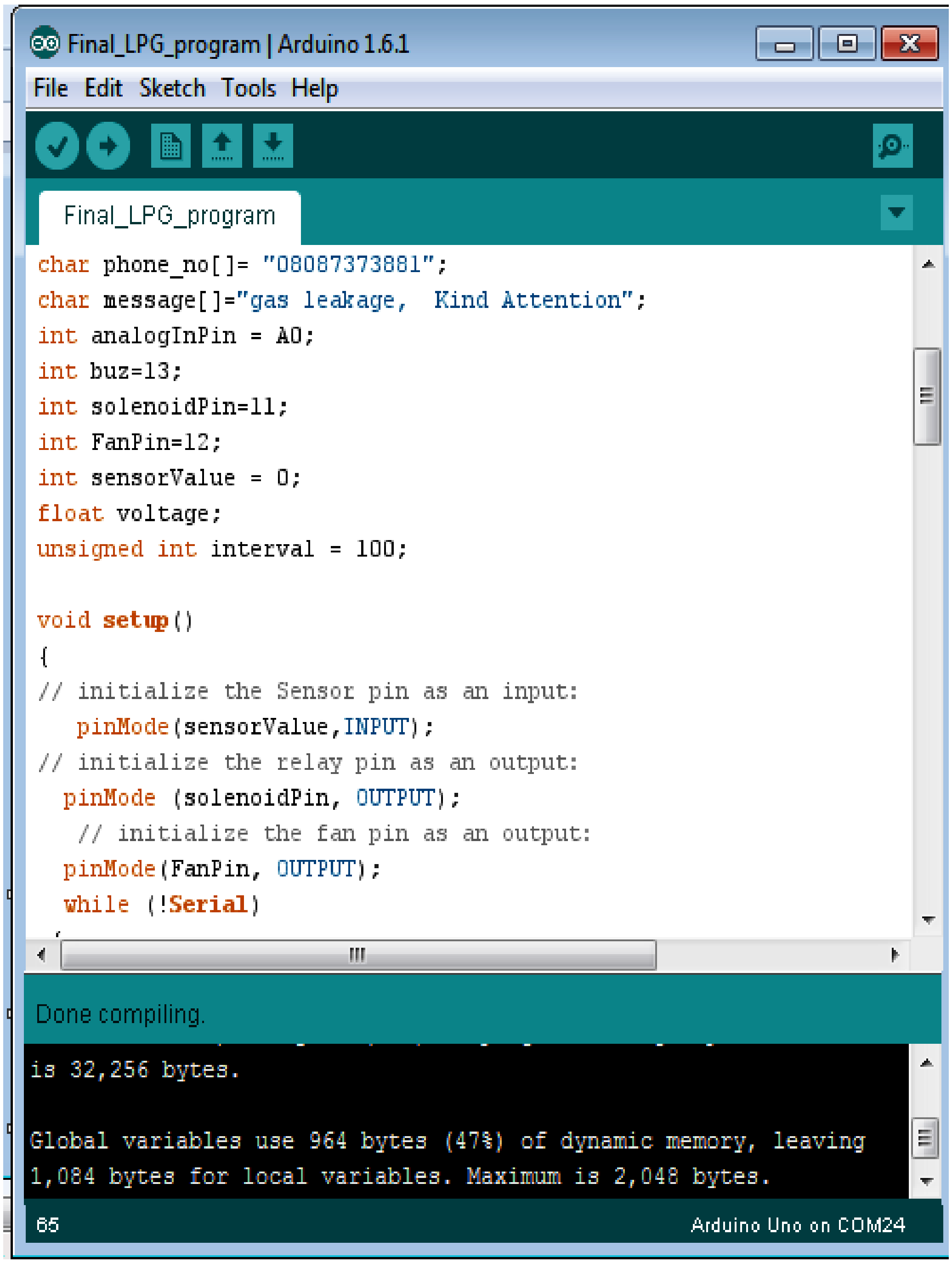


Fig. 3.19. Arduino programming for gas leakage detection.

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CHAPTER IV

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CHAPTER IV

IMPLEMENTATION OF WIRELESS SENSOR NETWORKS TO MONITORING AND CONTROL OF HAZARDOUS GAS LEAKAGE DETECTION

4.1 Introduction

Wireless networking and distributed data processing of the embedded sensing / actuating nodes under tight energy constraints demand new approaches to the protocol design and hardware / software integration. The wireless sensor network (WSN), is emerging as a powerful platform for distributed embedded computing and data management [1-4]. It therefore, plays a vital role for real time applications. Since the last decade, significant research covering the areas such as routing and Medium Access Control protocols, sensor device designs, implementation, energy management, operating systems, simulation, security, localization, deployment etc is underway in the field of WSN [5-7]. Moreover, sensor networks share a number of challenges such as energy constraints and routing. Compared to the use of a few expensive (but highly accurate) sensors, the strategy of deploying a large number of inexpensive sensors has significant advantages, at smaller or comparable total system cost, much higher spatial resolution, higher robustness against failures through distributed operation, uniform coverage, small obtrusiveness, ease of deployment, reduced energy consumption, and consequently increased system lifetime. The main aim of the wireless sensor network is to collect data from densely deployed WSN nodes in the homogeneous or heterogeneous way [8-9].As the sensor nodes are battery operated, rendering energy must be wisely managed in order to extend the lifetime of the network. Therefore, during implementation, the use of energy efficient protocol must be considered [10-12]. The sensor node is designed to detect the leakage of the gas. Thus, the response of the gas leakage detection can be obtained immediately and managed to obtain data from a scene of accident and display it in

the monitoring system. The present system uses a LabVIEW tool to monitor the leakage of gases. Also, GUI created using LabVIEW tool is more interactive, facile and effective. The chapter also deals with the complete implementation of WSN nodes and monitoring of the wireless gas sensing system.

4.2 A Wireless Gas Sensing System: A WSN Node Design

The Wireless Sensor Nodes, by designing both hardware and firmware and calibration are ready for establishment. Moreover, the co-ordinator node was also designed and made available for the system. The system was implemented with a star network topology consisting of five nodes. Four nodes were used for the detection of gas leakage and one node was used as a co-ordinator node to alert the users by sending SMS on their mobile phone. The data acquired from rest of the nodes (except the co-ordinator) were transmitted wirelessly using ZigBee protocol to the co-ordinator node and was kept on the web server for accessing the data through internet from anywhere. The WSN nodes were termed as the sensor node 1, sensor node 2, sensor node 3, sensor node 4 and a co-ordinator node. The hardware design modules designed using various hardware components are presented in figures 4.2, 4.3, 4.4 and 4.5, which show the hardware modules developed for the wireless gas sensing system. The PCB design and its layouts for WSN nodes are shown in fig.4.1 (a, b).

The wireless sensor node for LPG gas detection and monitoring is implemented in this thesis based on an arduino nano microcontroller that utilizes XBee S2 protocol to create sensing phenomena. Thus implementing a WSN model, we study some design factors that affect the system design. Although the design of sensor nodes differs from application- to- application, the basic structure is similar. The architecture of sensor node consists of a processing unit which is responsible for collection and processing the data sensed by a sensor. A radio transceiver works as the communication unit among sensors and a battery is the power supply unit in this system.

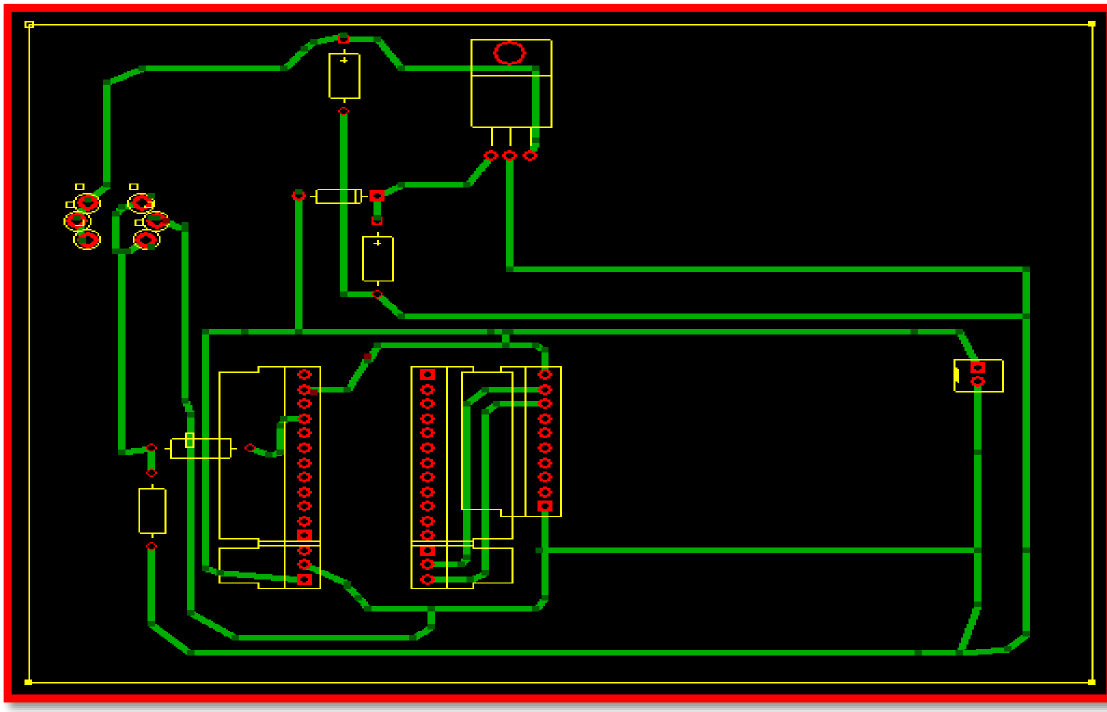


Fig.4.1. a) PCB layout of a wireless gas sensing system.

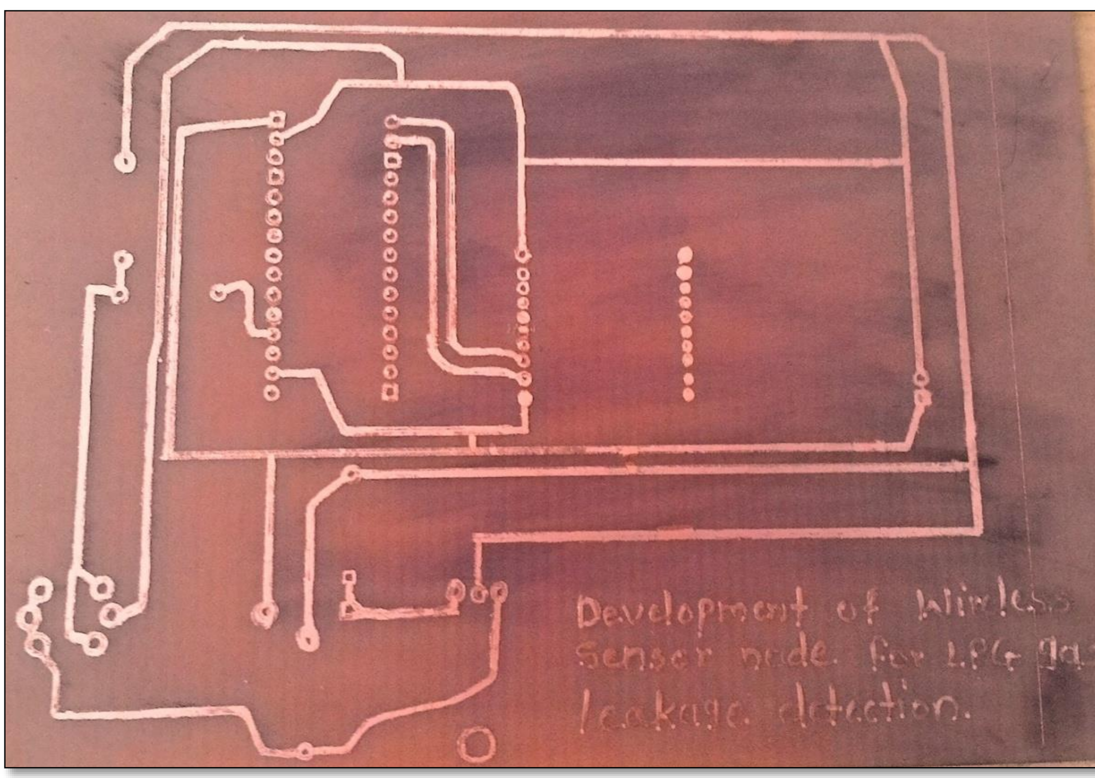


Fig. 4.1.b) PCB layout of a wireless gas sensing system.

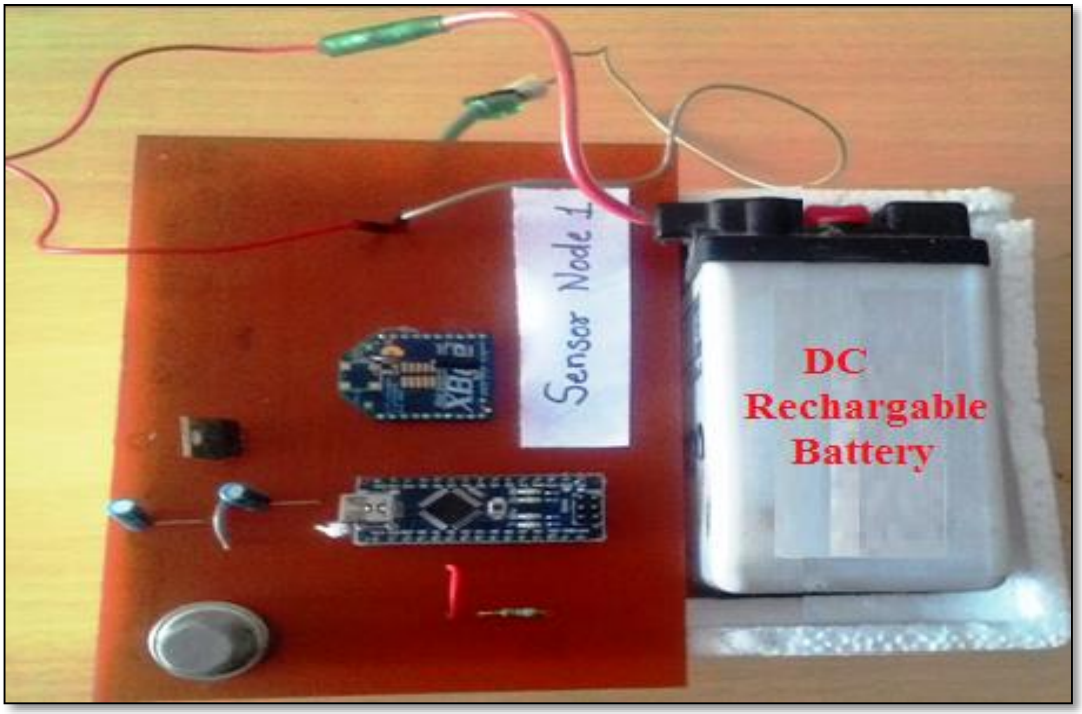


Fig.4.2. The WSN node 1 designed to monitor LPG gas leakage.

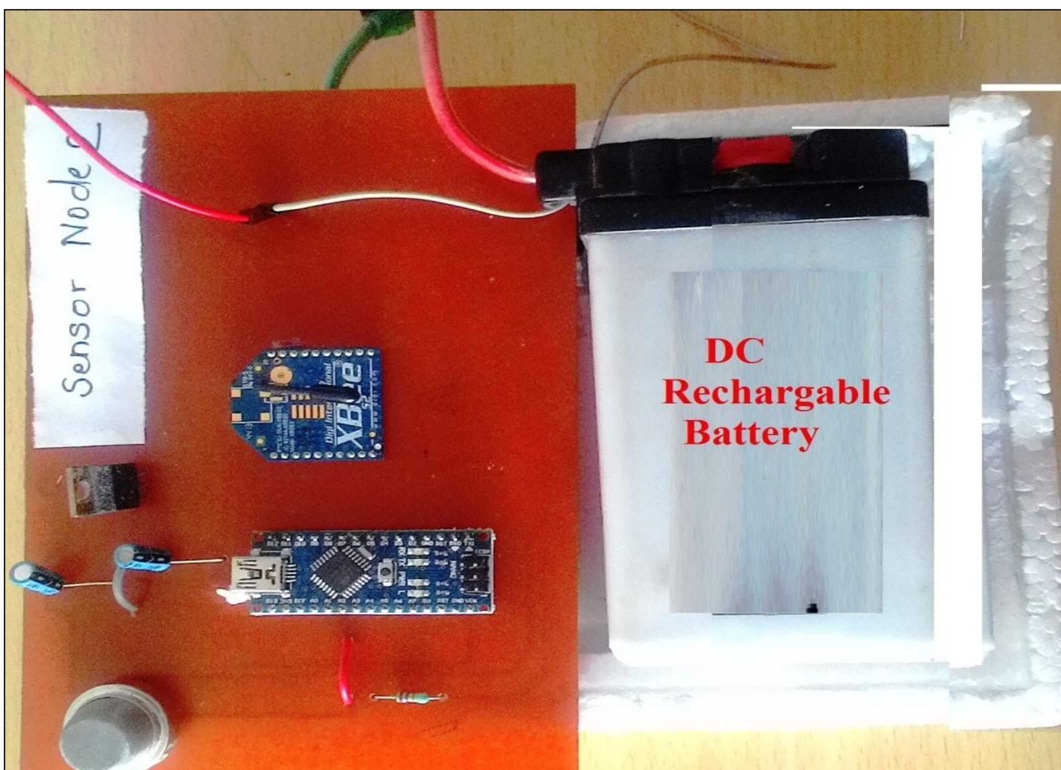


Fig.4.3 The WSN node 2 designed to monitor LPG gas leakage.

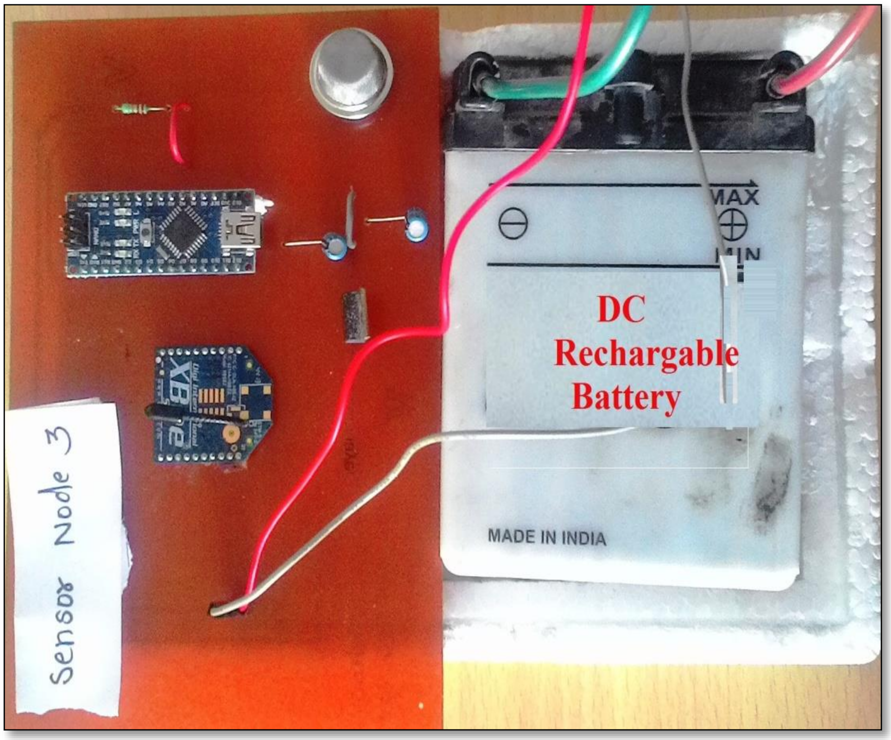


Fig.4.4 The WSN node 3 designed to monitor LPG gas leakage.

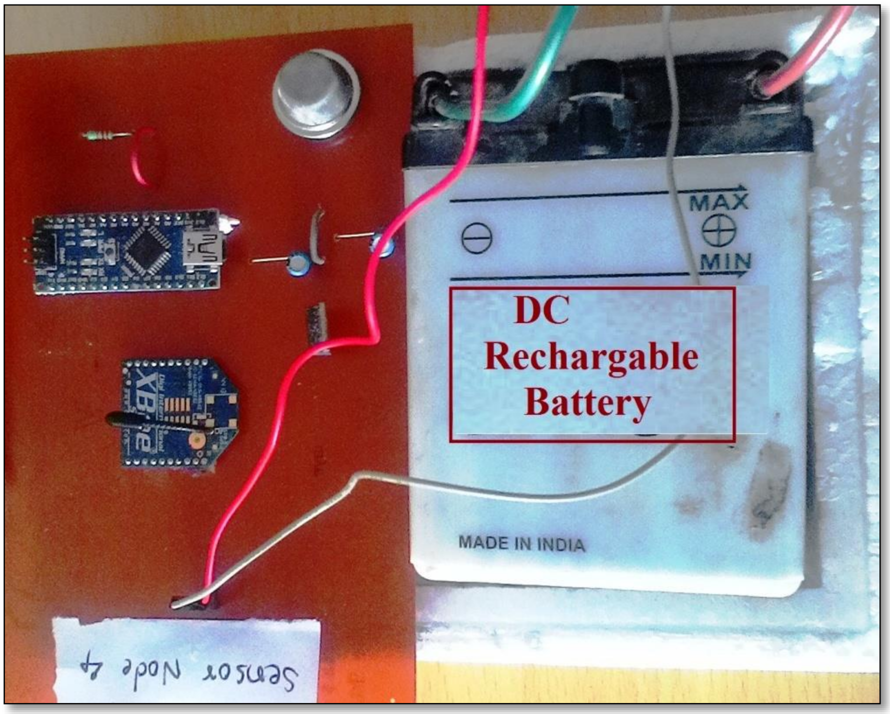


Fig.4.5 The WSN node 4 designed to monitor LPG gas leakage.

The experimental setup of the co-ordinator node is shown in fig.4.6.

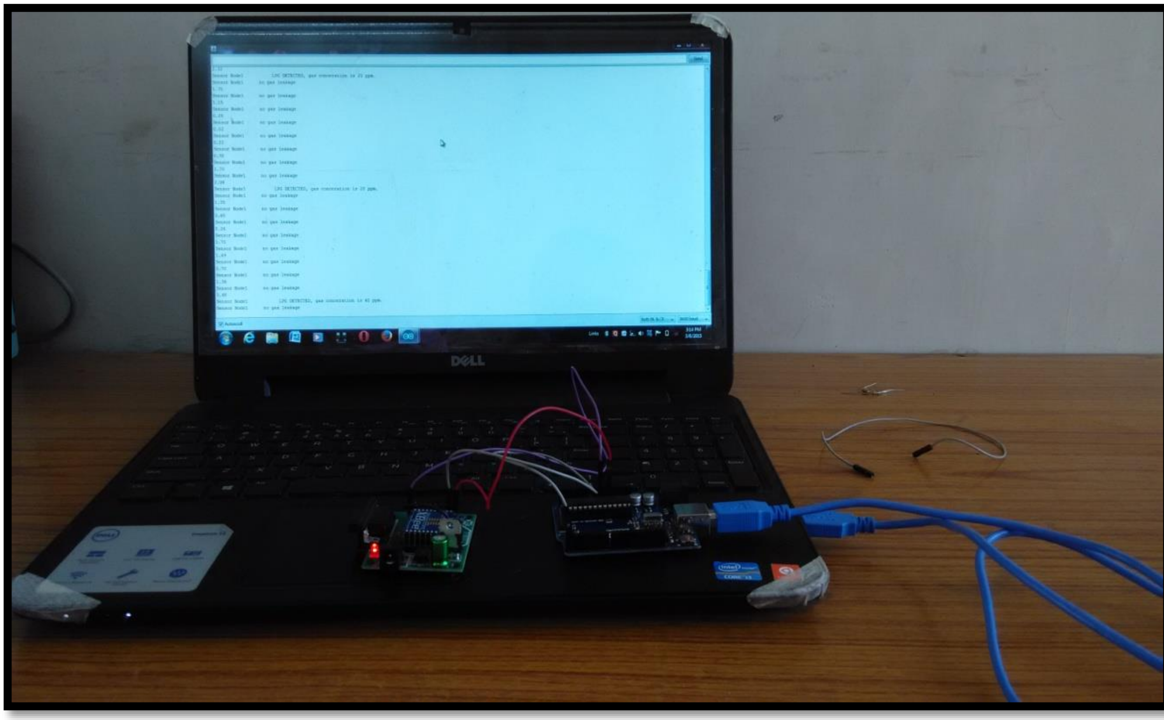


Fig.4.6 The experimental set up of a co-ordinator node to monitor LPG gas leakage.

All these nodes are associated with their own primitives. The nodes ID are given in the following table.

Sensor Node	**Node ID**
Sensor Node 1	AA
Sensor Node 2	BA
Sensor Node 3	CA
Sensor Node 4	DA

Table4.1- The list of the WSN nodes and their respective ID'S.

The co-ordinator node is also designed. Now, the system is ready for the

implementation for which it has been designed. The system will be implemented in a room where leakage can happen.

4.2.1 The node data management in LabVIEW

We proposed four sensor nodes and one co-ordinator node. The respective Id's for each sensor node is shown above. To separate the data coming from each sensor node, the LabVIEW programming was done as follows-

i. The LabVIEW was interfaced to the co-ordinator node (arduino UNO board) through VISA function tool.

ii. The co-ordinator node received the data from each sensor node.

iii. The separation of the data from each sensor node was done in LabVIEW.

The results obtained after coming the data from various sensor nodes through co-ordinator node in LabVIEW are as follows.

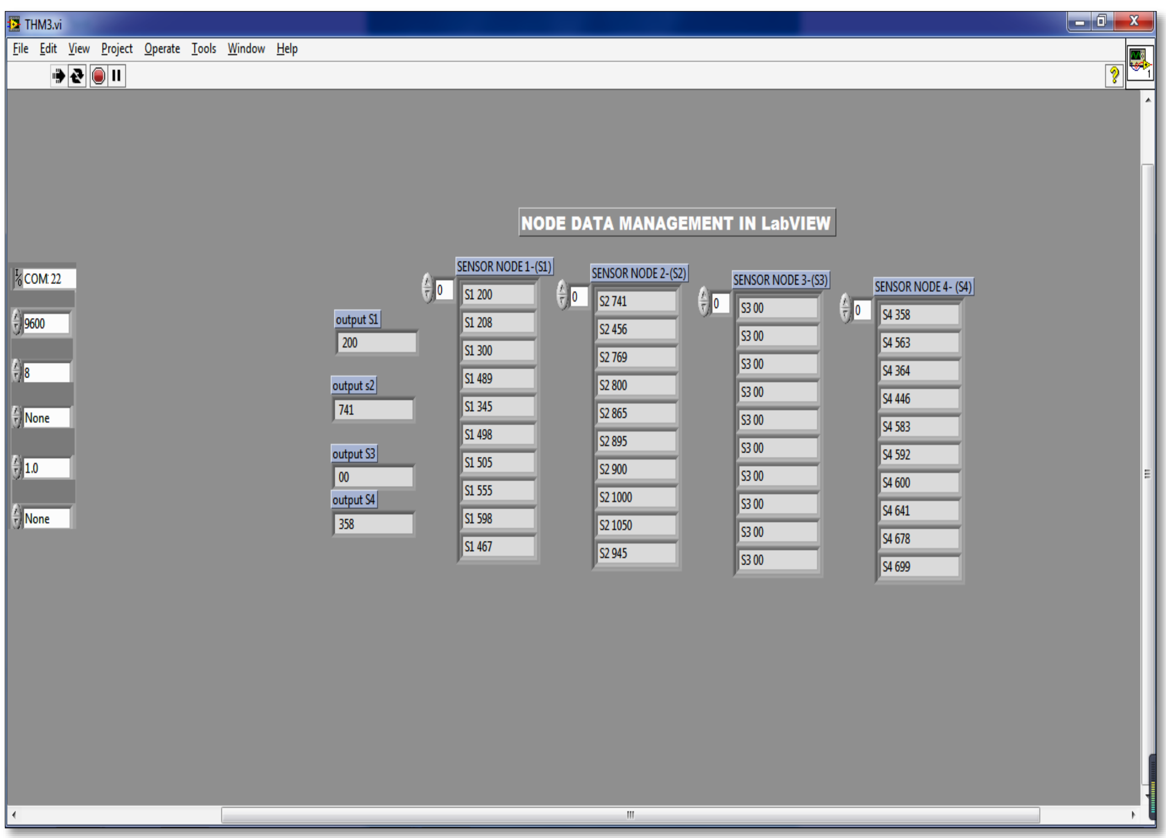


Fig.4.7 The node data management in LabVIEW.

4.3 Implementation of Wireless Gas Sensing System at Room (Lab.)

The WSN system consisting of wireless sensor nodes and co-ordinator node was established by deploying the star topology and implemented to monitor the room where the gas was leaking. In fig.4.8 LPG gas sensors deployed in a room or home at various locations are shown below.

Fig.4.8 Implementation of sensor nodes in a room.

The prototype model developed for a gas sensing system in LabVIEW is shown in fig 4.9. If the gas concentration is above 800 ppm, it enters in the

explosive mode and automatically buzzer becomes operative. To ensure the proper operation and to confirm the accuracy and reliability and to realize the phenomenon of collaborative collection of environment data, the present WSN system was established in a room where gas leakage happened. Here, all nodes were battery operated. Therefore, fully charged batteries were installed in each WSN node. The experiment was carried out in the period from 11am to 1 pm. All the WSN nodes collect the gas leakage data and after processing, they send the same towards the co-ordinator node. The co-ordinator node was supported to be centralized control room.

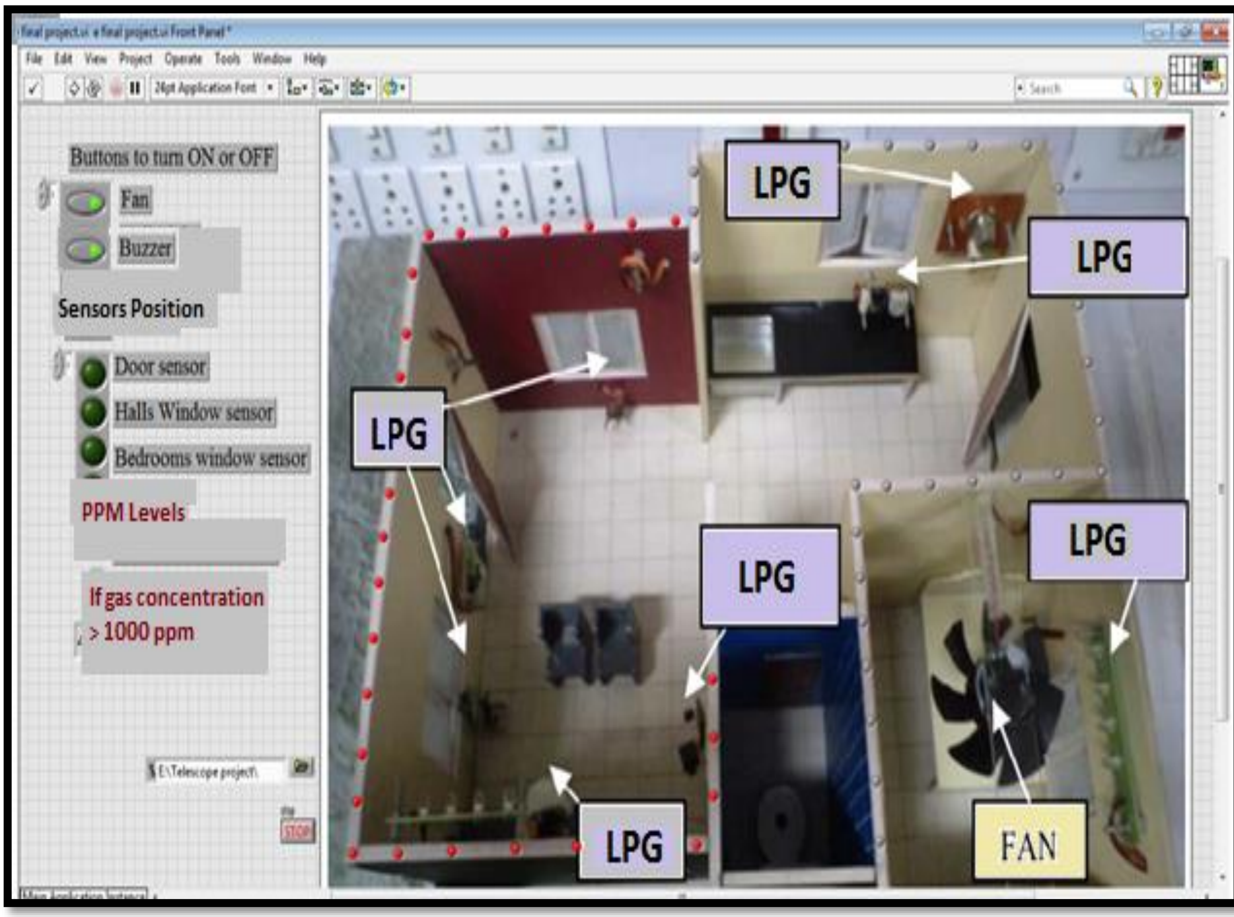


Fig. 4.9. A prototype model for implementation of gas sensing system at room / lab./home.

When the power is made ON, the sensor node starts transmitting parameter values towards co-ordinator node. The co-ordinator node was equipped with

Laptop, wherein dedicatedly designed Graphical User Interface (GUI) was installed.

The co-ordinator node continuously receives the data and sends it to the internet browser. Moreover, GUI created in LabVIEW is also having provision to store the data in real time.

4.4 Graphical Analysis of a Wireless Gas Sensing System

The plot in fig. 4.10 illustrates the data monitoring of the gas concentration in PPM versus time, which was created by a Microsoft Excel from the LabVIEW built-in export function. It happens that leaked gas concentration increases with time and it reaches the threshold value of dangerous limit and the system sends an alarm signal to alert the users. Besides, users are able to track the condition of the room in real time and may record the data as a back-up for maintenance / checkup purpose. The gas leakage detection data were collected for a period from 11:05 am to 11:26 am and is as below. Testing was carried out manually releasing LPG into atmosphere around sensor for one sensor node.

Time (Minutes)am	Gas concentration (ppm)
11:05	200
11:06	205
11:07	210
11:08	230
11:09	240
11:10	260
11:11	280
11:12	200
11:13	300
11:14	310
11:15	350
11:16	355

11:17	300
11:18	210
11:19	205
11:20	208
11:21	210
11:22	208
11:23	207
11:24	206
11:25	205
11:26	204

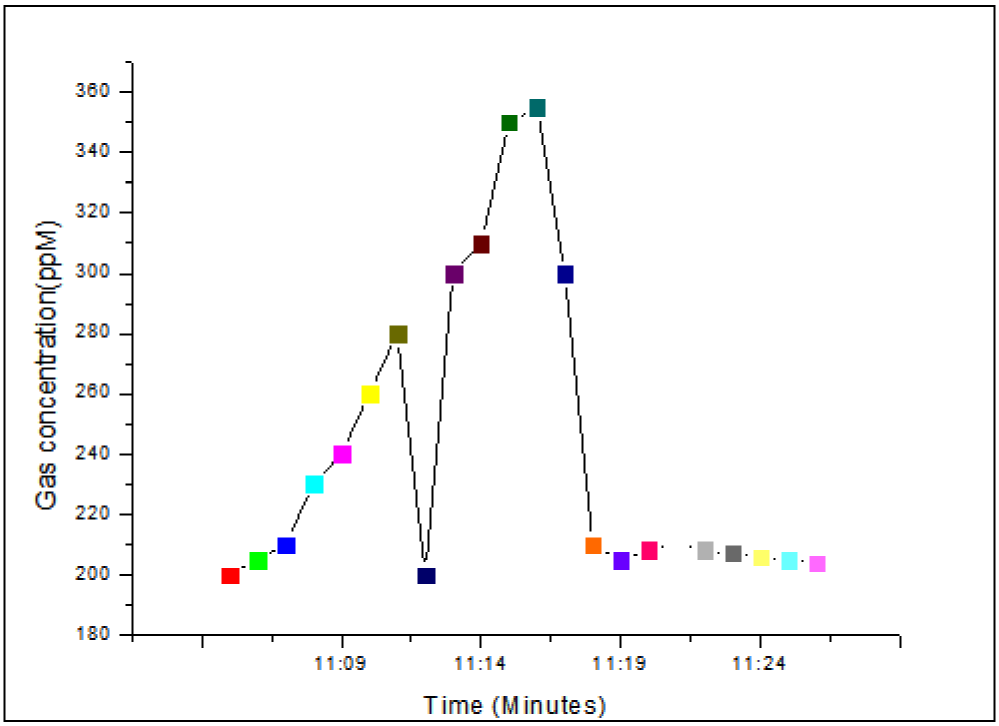


Fig.4.10. Graphical representation of gas leakage detection.

As we increase the leakage of LPG gas level then the gas concentration increases, if we decrease the gas level then suddenly it reaches to zero then again it increases slowly.

In another experiment data were collected for identification of explosive level of gas leakage detection and was carried out manually from 12:00 pm to 13:05 pm. This is shown below.

Time (Minutes) pm	**Gas concentration (ppm)**
12:00	400
12:03	480
12:06	520
12:09	570
12:12	600
12:15	700
12:18	800
12:21	900
12:24	920
12:27	990
12:30	1000
12:33	950
12:36	800
12:39	750
12:42	725
12:45	700
12:48	650
12:51	630
12:53	620
12:55	600

1:02	590
1:05	560

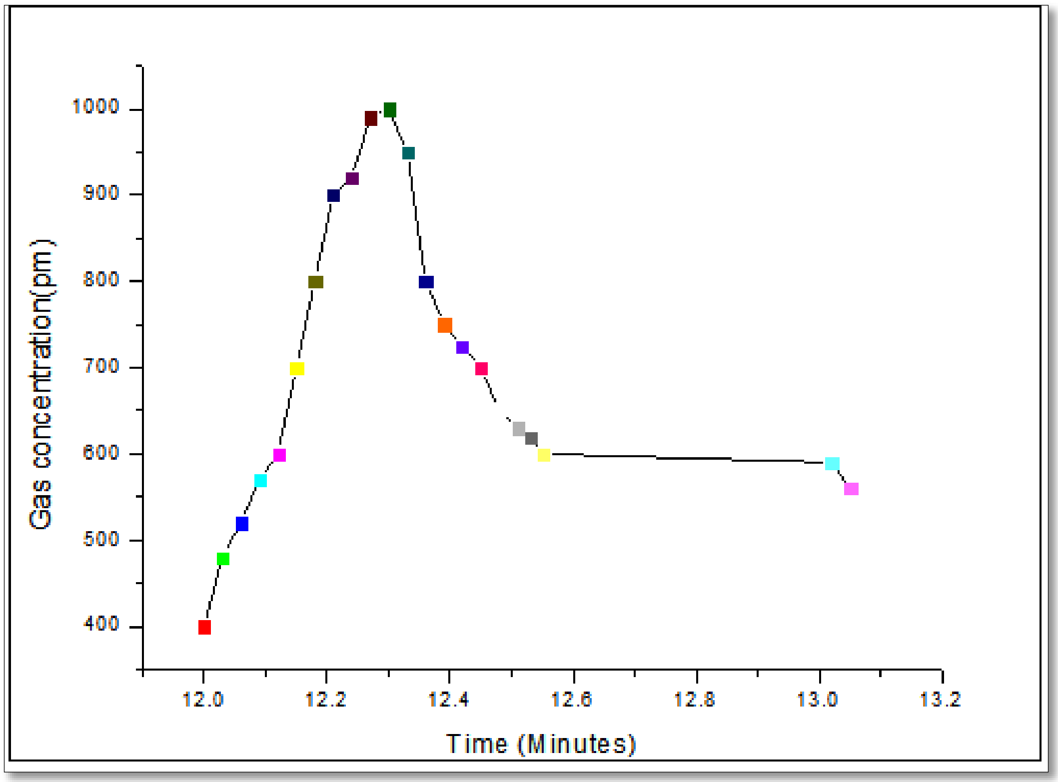


Fig.4.11 Graphical representation of gas leakage detection (explosive level).

The data were plotted (fig. 4.11) and it show the leakage of gas concentration that reaches the threshold value of explosive limit (which exceeds 800 ppm). Therefore, the system will send an alarm signal to alert the users as well as send an alert SMS to the user. As we increase the LPG gas leakage level up to the explosive level, it increases to the 800 ppm. If we stop the gas leakage level, then it slowly reaches to the zero.

4.5 The Virtual Instrument Software Architecture (VISA): LabVIEW.

LabVIEW is used in the monitoring of the wireless gas sensing system. Therefore, for interfacing the data transfer by ZigBee in the LabVIEW, Virtual

Instrument Software Architecture (VISA) configuration serial ports are required. VISA is the lower layer of the functions in the LabVIEW instrument driver VIs that communicates to the driver software in the PC to communicate it to external I/O devices such as ZigBee modules.

4.5.1 Supported platforms and environments

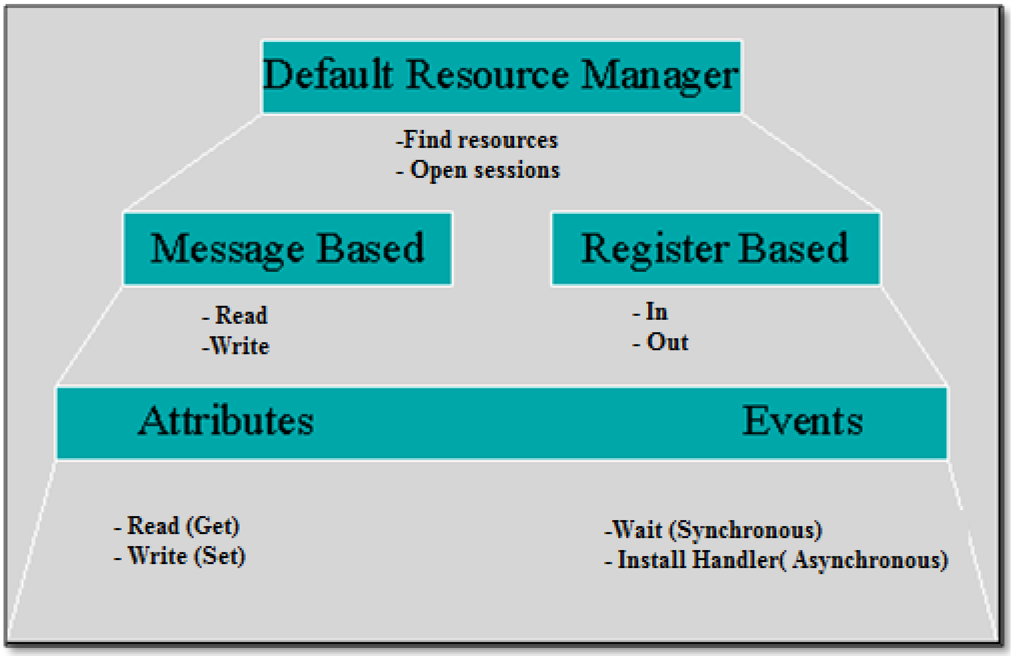
The platforms and environments that are supported by NI-VISA are shown in the table below.

Platform	Environment
Macintosh	LabVIEW, C
Windows 3.1	MSVC, Borland C++, CVI, LabVIEW, VB
Windows 95/NT	C, CVI, LabVIEW, VB
Solaris 1	CVI, LabVIEW
Solaris 2	CVI, LabVIEW
Hp-Ux	CC, CVI, LabVIEW

Because VISA is the language used in writing instrument drivers, most instrument drivers currently written by National Instruments support all of these environments.

4.5.2 VISA programming

VISA is an object-oriented language. The most important objects in the VISA language are known as resources [13]. In VISA, these variables are known as attributes. A simplified outline of the internal structure of the VISA language is shown in the figure below.



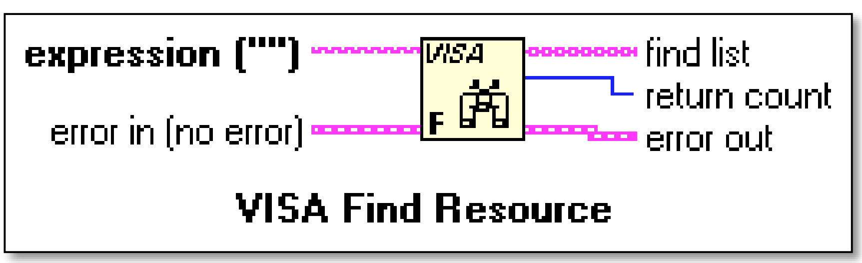
a) **Default resource manager, session, and instrument descriptors.**

- The default resource manager is at the highest level of VISA operations. Communication must be established with the resource manager at the beginning of any VISA program. This immediately brings up two terms; a) resource and b) session that need to be defined.

Resource is an instrument or controller.

Session is a connection, or link, to the VISA default resource manager or a resource.

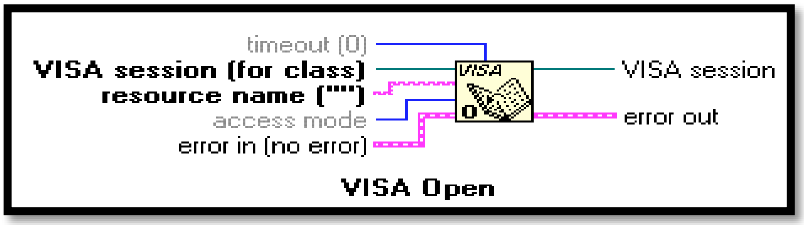
The VISA Find Resources VI can be used to determine whether all of the necessary resources for the application are available to run.



b) **Instrument descriptor** – This is the exact name and location of a VISA resource. This string has the format;

Interface Type [Board Index]:: Address::VISA Class.

The VISA Open VI that carries out this operation is shown below.



c) Serial interface to VISA

Serial Baud Rate– The baud rate for the serial port.

Serial Data Bits– The number of data bits used for serial transmission.

Serial Parity– The parity used for serial transmission.

Serial Stop Bits– The number of stop bits used for serial transmission.

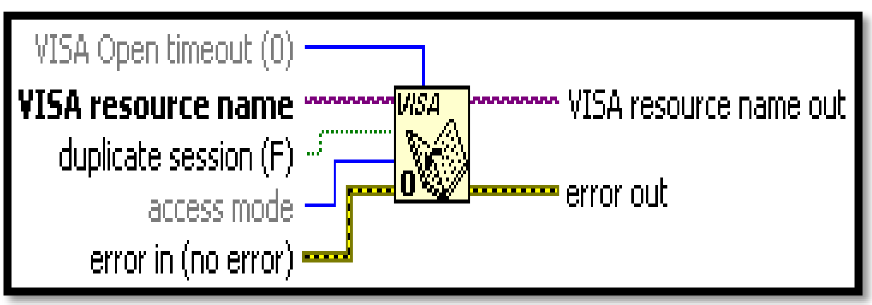
d) Operation prototypes

The following section specifies the operation prototypes for LabVIEW.

Common controls and indicators

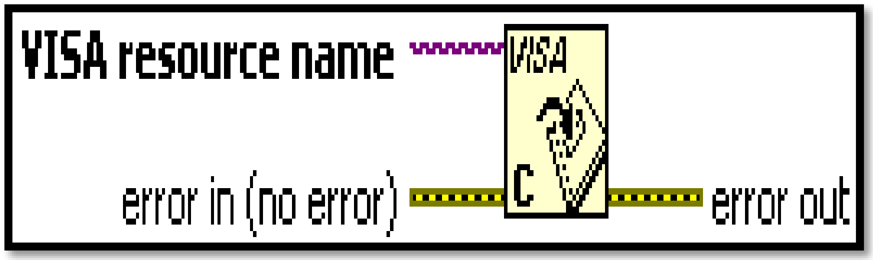
Each VISA VI has an Error In and an Error Out terminals defined on its connector panel in the lower left and lower right terminals, respectively. The error clusters are used to report all VISA completion and error codes. A benefit of error input/output is that data dependency is added to VIs that is not otherwise data dependent, thus adding a means of specifying execution.

1. ViOpen (VISA Open)



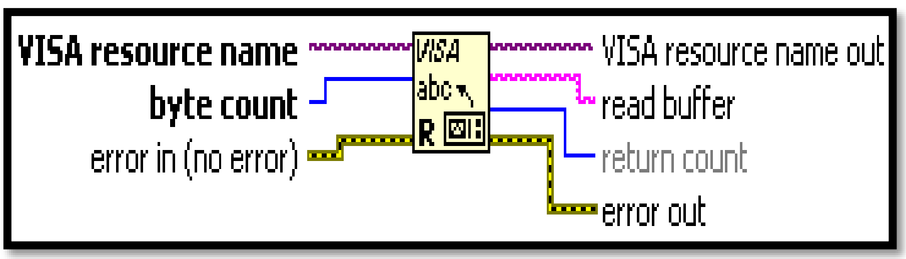
If "duplicate session" is False and a session to the resource is already open, then ViOpen is not called.

2. **ViClose (VISA Close)**



ViClose will execute even if an error condition is passed in through the error in cluster.

3. ViRead (VISA Read)



The wireless gas sensing system is implemented using VISA interface block diagram as shown in figure 4.12. There are three levels for the visa interface which are configured serial port, VISA read and VISA closed. All three of the parts are a must have for the interfacing process.

The first level visa configured serial port is for initializing the serial ports specified by visa resources named to a specified settings. Wire data to the visa resources named input to determine the polymorphic instance to use or manually select the instance. In this wireless gas sensing system, COM 22 has been chosen as the ZigBee port in that location. Besides, the value of 9600 in the figure 4.12 shows the baud rate of the system from arduino and ZigBee. The grey line in the figure shows the while loop for repeating the sub diagram inside it until conditional terminal, an input terminal receives a particular Boolean value. The Boolean value depends on the continuation behaviour of the loop.

After interfacing the data transfer and LabVIEW finish, the next process is to read the data transfer. To read the data transfer VISA read tool is used. Once the string number from visa has been changed, the output number needs to convert back into the original voltage value. As mentioned before, Arduino will read the data in the 10-bit data format only. Therefore, to convert the value in the original voltage we use

$$\textbf{Digital output} = \frac{Vo}{5} \textbf{x 1024.}$$

Then in the LabVIEW, we used various GUI for user monitoring. The range will conduct the voltage value according to the threshold value that has been set before. The actual VISA programming for node data management in LabVIEW is as follows.

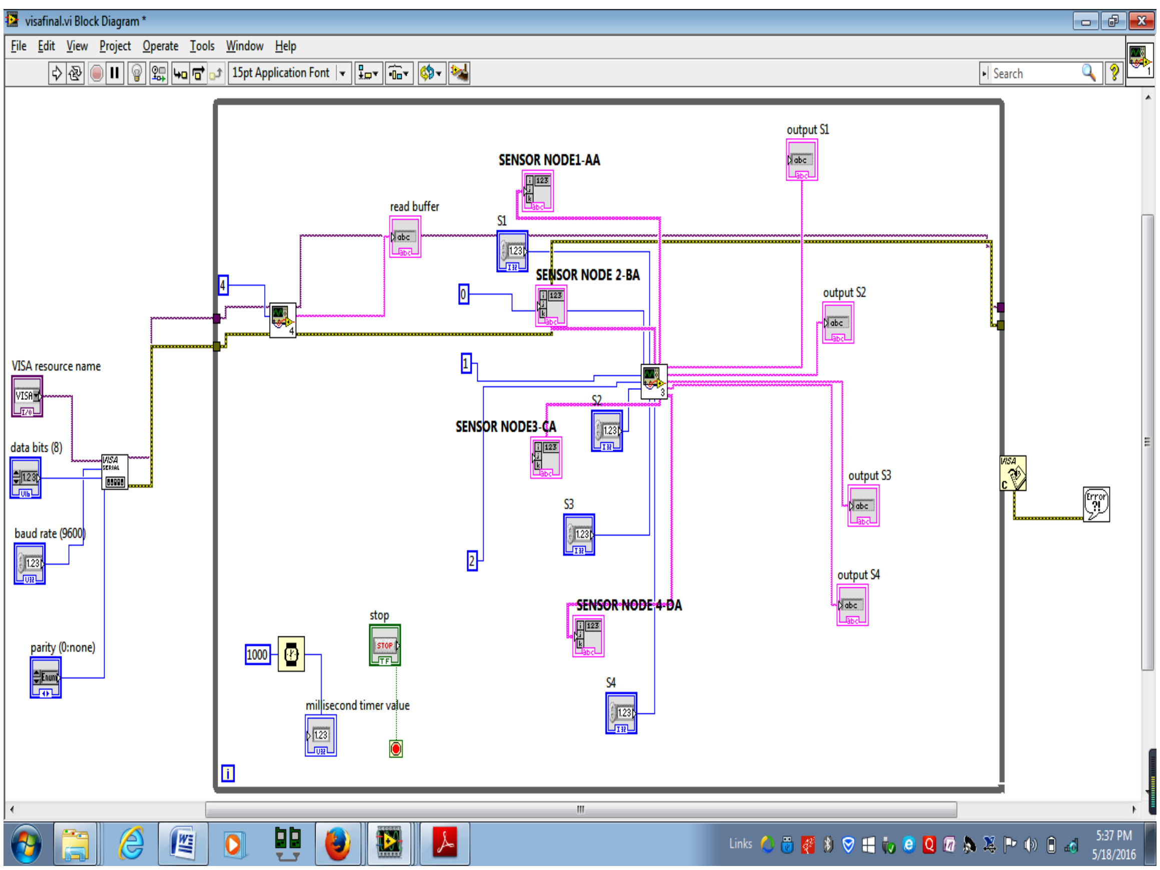


Fig. 4.12. VISA interface block diagram for four sensor node detection.

The VISA programming for displaying the status of four sensor nodes on front panel of LabVIEW is shown in fig.4.13.

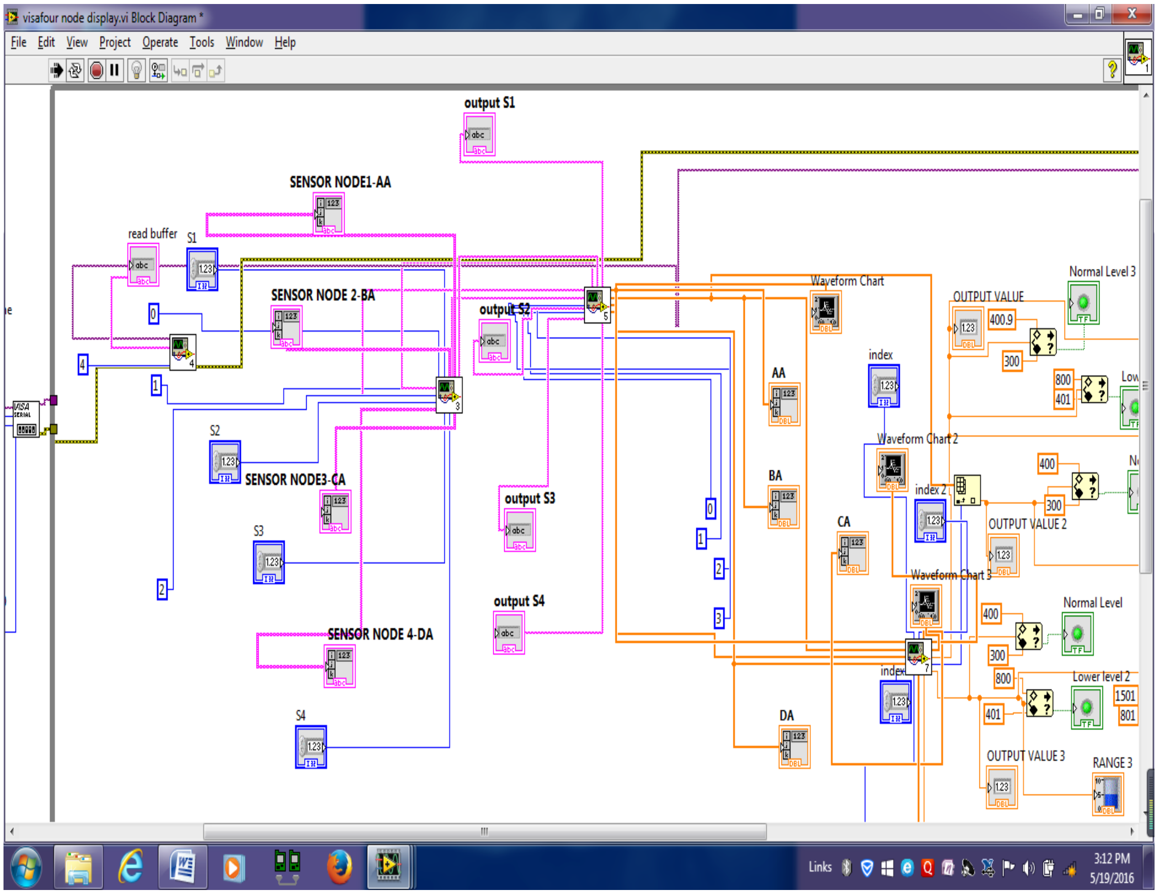


Fig. 4.13. Block diagram for monitoring of four node condition.

4.6 Monitoring of LPG Leakage Using LabVIEW

The LabVIEW GUI was used to monitor the leakage level of the gas concentration. LabVIEW is system-design software that allows to program tools on a GUI for the measurement and control of systems. It also allows the user to program graphically in a language called “G”. This programming method allows the user to wire graphical icons together while directly compiling to the computer, greatly simplifying the debugging process. G programming is much more intuitive because it allows scientists and engineers to think and to solve the problems visually. One benefit of the built-in compiler is the broken run arrow in the toolbar that does not allow the user to run the program if there is an error. LabVIEW is able to connect to the serial port on the Arduino Uno to read the live data. Also, it has the capability to read or write to spreadsheets. Because of the intuitive

programming language and applicable measurement tools provided, LabVIEW offered a very straightforward approach for designing a graphical user interface (GUI) system. It offers an unrivaled integration with thousands of hardware devices and provides hundreds of built-in libraries for 14 advanced analyzed and data visualization; all for creating virtual instrumentation. The model was tested by using LPG, the increasing value of the gas concentration and voltage output showed presence of gas leakage. The control program is realized using LabVIEW from National Instruments and is executed in the control computer. The aims of this program are: to configure the nodes and the network and capture the measurements made by the sensor nodes through the co-ordinator node using USB (between the PC and co-ordinator) and ZigBee interface (between co-ordinator node and the sensor nodes) as shown in the following block sketch (fig.4.14). The program has two important blocks: the front panel, where the interaction between the user and the program is made and the block diagram, where the code of the virtual instruments is programmed.

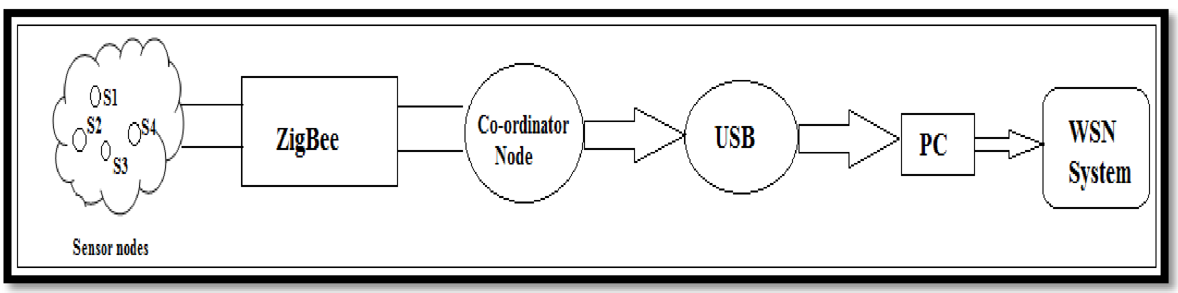


Fig. 4.14. Block sketch of WSN showing operational elements.

The gas leakage response for wireless gas sensing system was plotted in LabVIEW for two conditions:

a) When gas leak detected in a room

The LabVIEW front panel will display the response when gas leakage is detected in the room. The threshold value given for this sensor is according to the OSHA standard (described in chapter 2).As the PPM value reaches to its threshold level, then gas is detected in the room and is displayed on LabVIEW (fig.4.15).

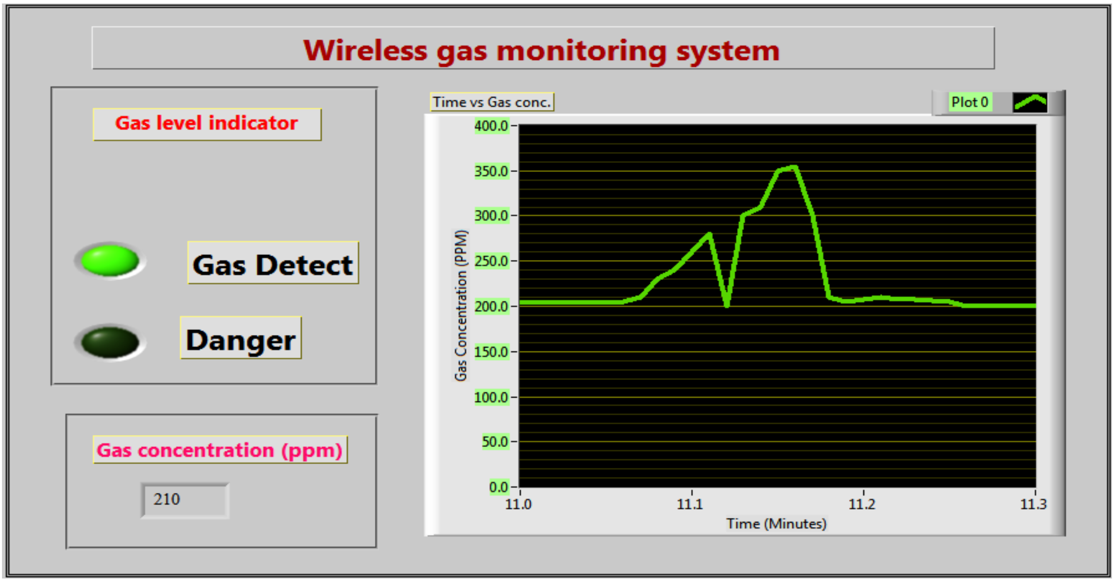


Fig. 4.15.GUI of gas leakage detection.

b) When gas leakage in dangerous condition

When the response of the gas leakage is in dangerous condition, it is immediately displayed on the monitoring system using LabVIEW as follows. As the dangerous condition occurs, red LED will glow on the front panel of LabVIEW. This is shown in fig. 4.16.

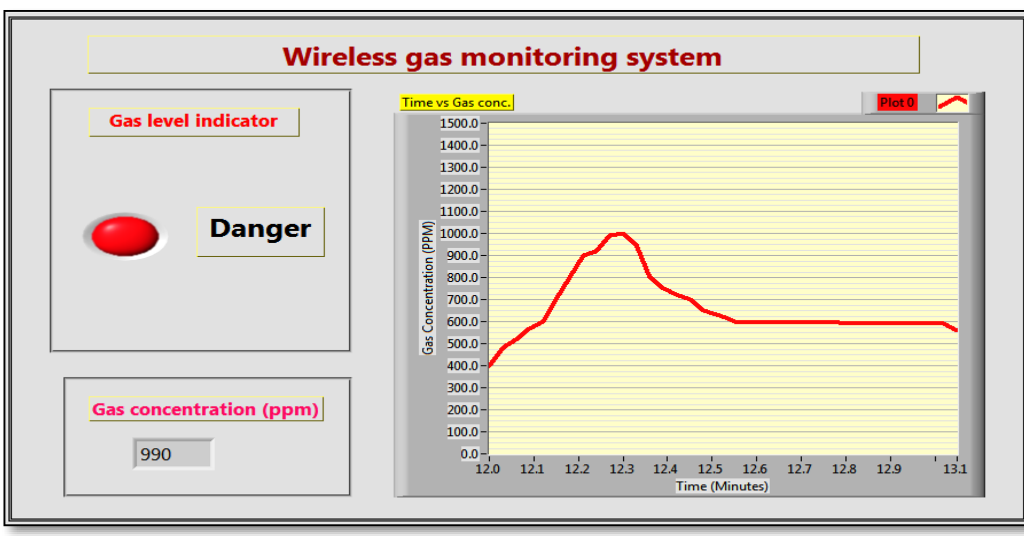


Fig. 4.16. GUI of gas leakage in dangerous condition.

The GUI created using LabVIEW for gas leakage level was done in two ways; the star display rating and the string display rating. The front panel shown in (fig.

4.15- fig. 4.19 and fig.4.21-fig.4.22) was separately designed for each node sub VI, included in the main VI shown in fig.4.13.

4.6.1 The star display rating of gas leakage detection

The LPG detection using LabVIEW is demonstrated using star rating for one sensor node. If the gas concentration is less than 400 ppm and sensor output voltage is less than or equal to 1.5V, then LabVIEW front panel displayed one star which indicated normal level of gas leakage. Here, a voltmeter and gas tank is provided, to ease users, to observe the level of gas leak. This is shown in fig.4.17.

If the gas concentration is in the 400 ppm to 800 ppm range and sensor output voltage is between 1.5V to 4.2V, then LabVIEW front panel displayed three stars, which indicated low level of gas leakage (fig.4.18).If the gas concentration is greater than 800 ppm and sensor output voltage is also greater than 4.2 V, then LabVIEW front panel displayed five stars, which indicated explosive level of gas leakage (fig.4.19). Based on the GUI, there are voltmeters and gas tank provided, to ease user's to observe the levels of the gas leak.

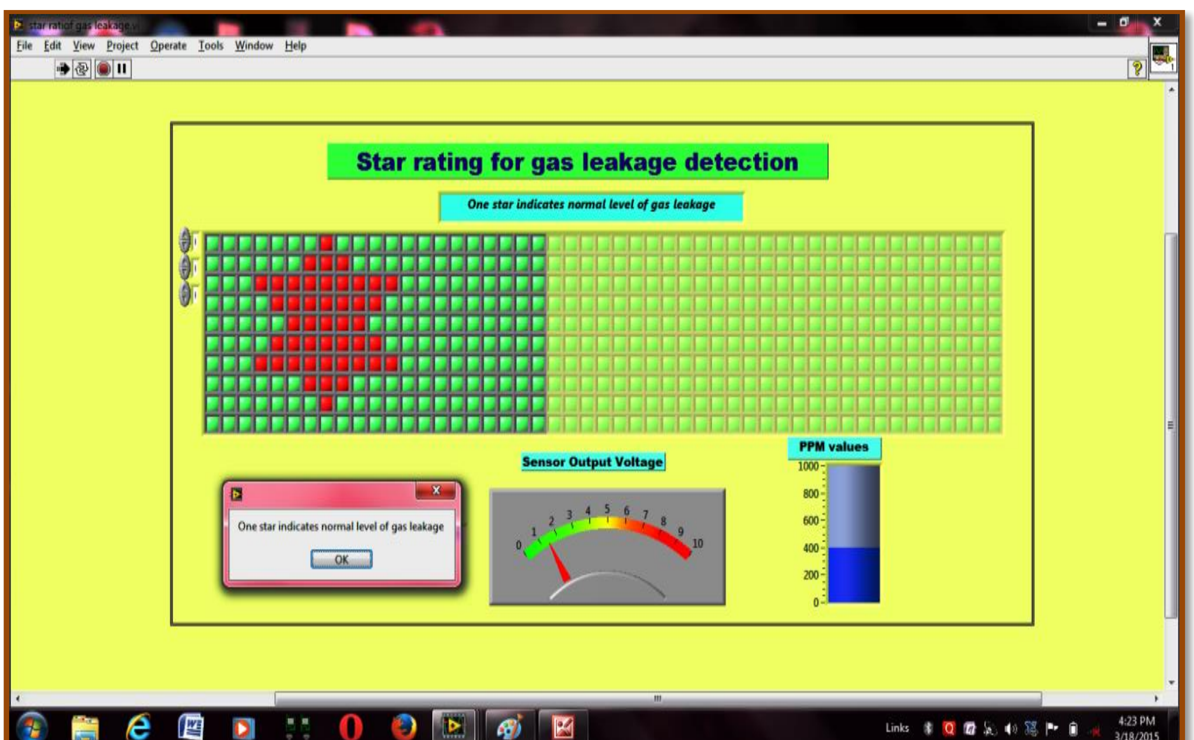


Fig. 4.17.Gas leakage monitoring system in normal level condition.

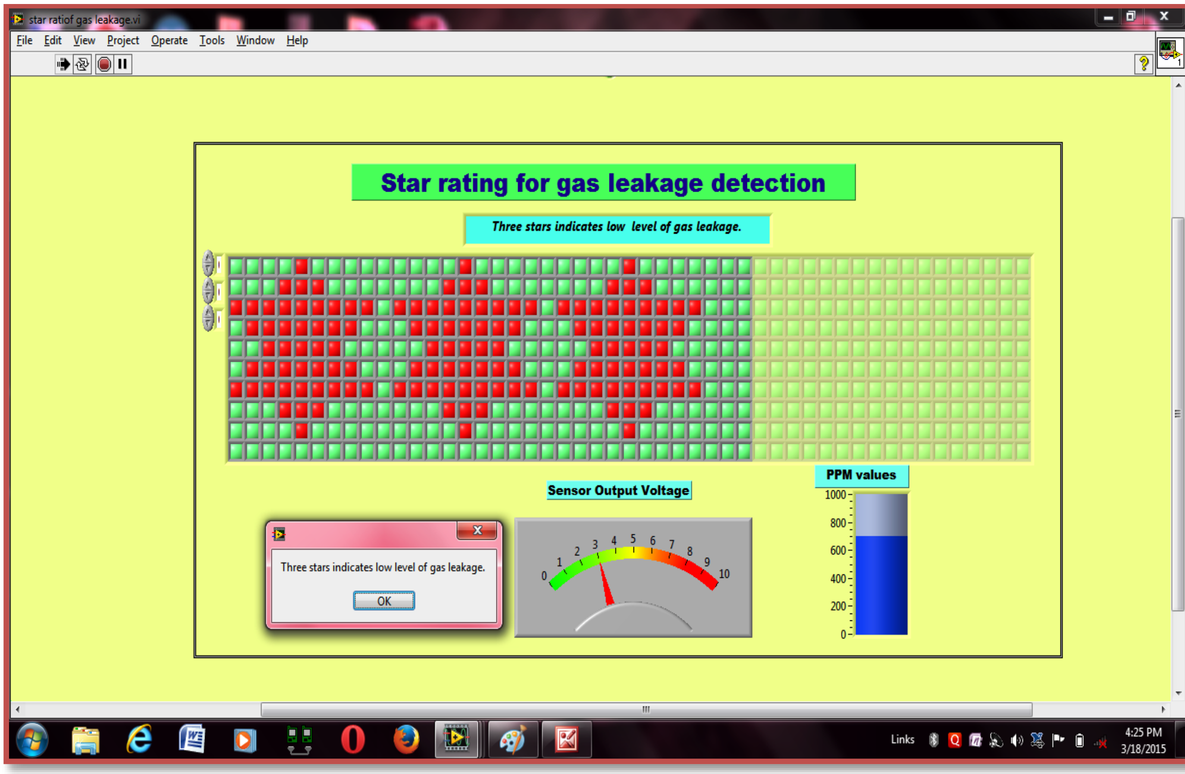


Fig. 4.18.Gas leakage monitoring system in low level condition.

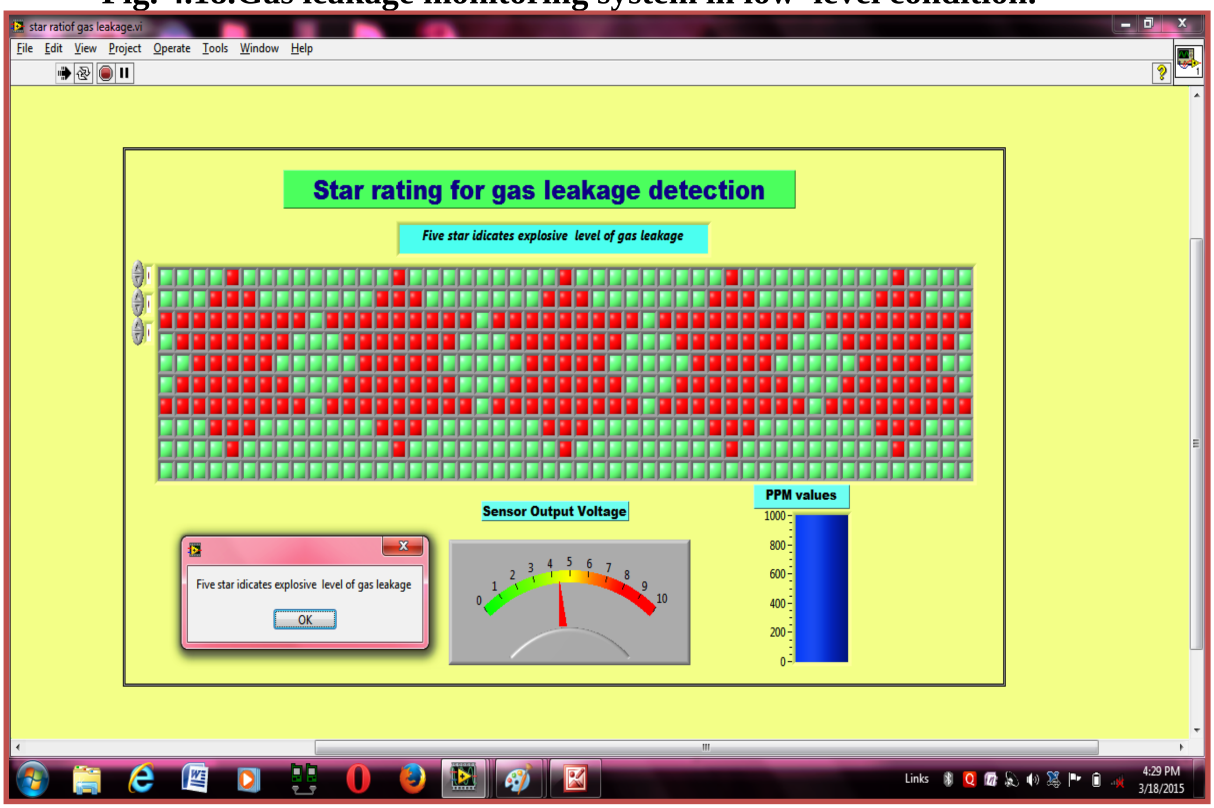


Fig. 4.19.Gas leakage monitoring system in explosive level condition.

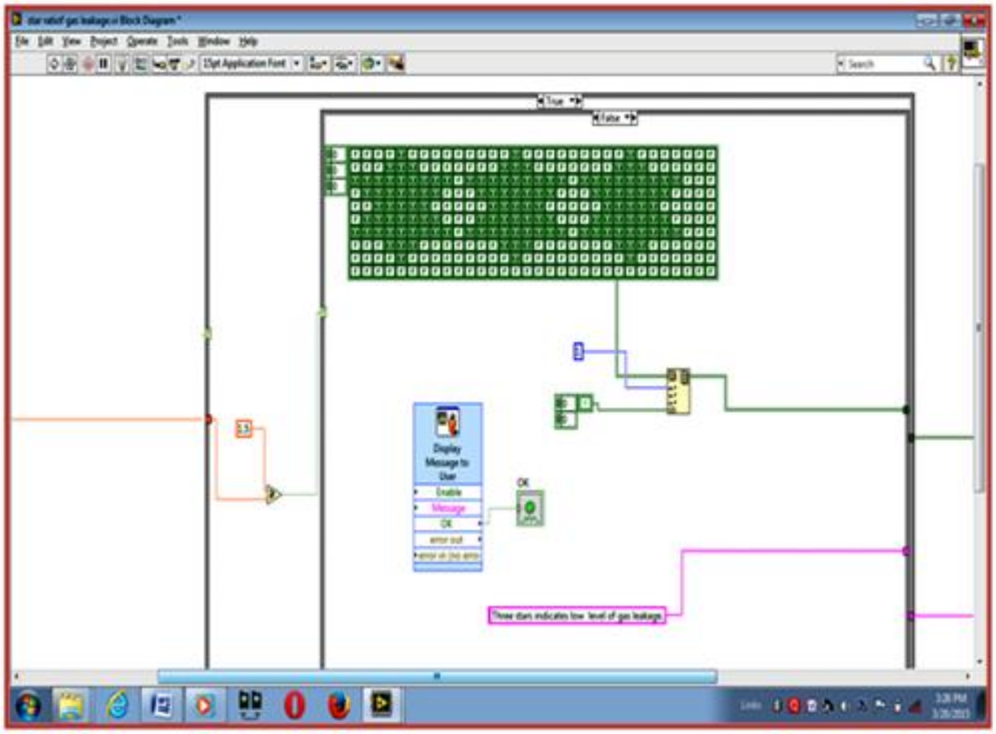


Fig. 4.20. Programming of star display rating.

The GUI of this model developed using LabVIEW shows three types of stars as the different conditions, in terms of normal level, warning, and the dangerous or explosive level. The graph in fig 4.9 and fig.4.10 are used to display the gas concentration versus time in every minute and the sensor's voltage output waveform. Besides, there is a voltmeter to show the voltage output from the gas sensor and the gas tank to indicate the concentration of leakage gas.

The programming of these is done by using block diagram in LabVIEW software**.**Fig.4.20 shows programming of GUI using LabVIEW software

4.6.2 The string display rating of the gas leakage detection

The front panel of the LabVIEW displayed the two levels of the gas leakage for the one sensor node in the form of string, i.e. normal level and explosive level. When the gas concentration was below 800 ppm, it indicated normal level. While, when the gas concentration was above 1000 ppm, it has shown explosive level of

the gas leakage. The simulation results are shown in figures 4.21 and 4.22.

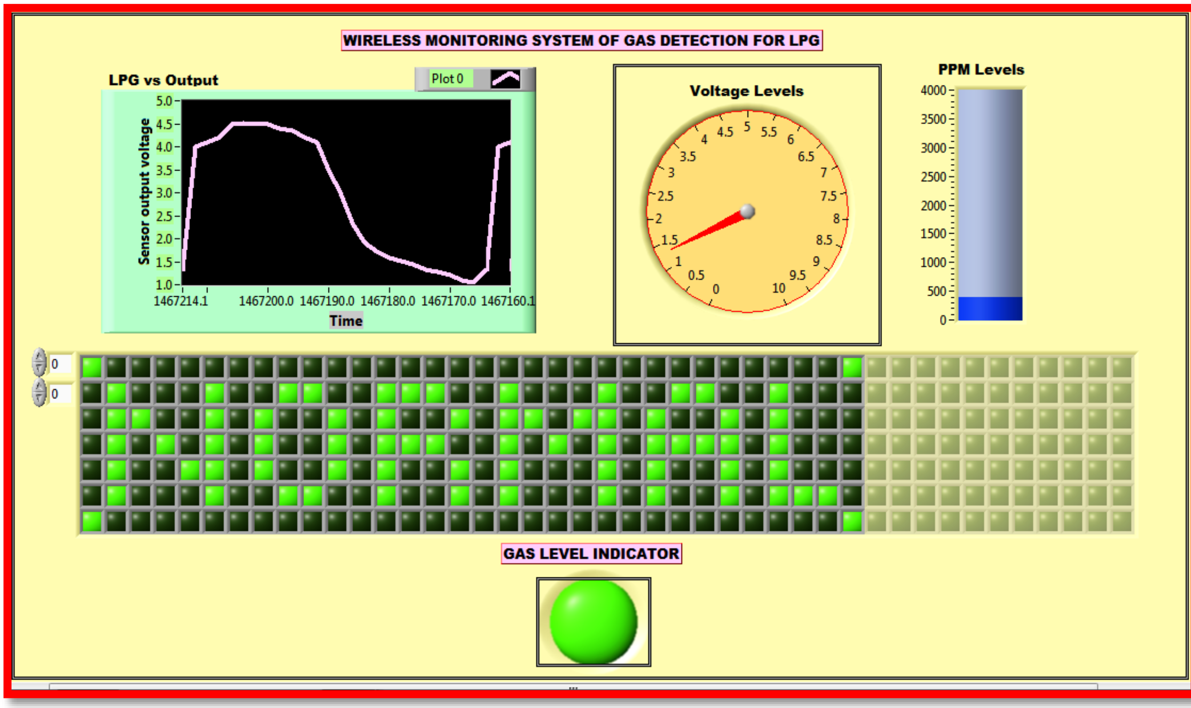


Fig. 4.21.Normal level indication of the gas leakage detection.

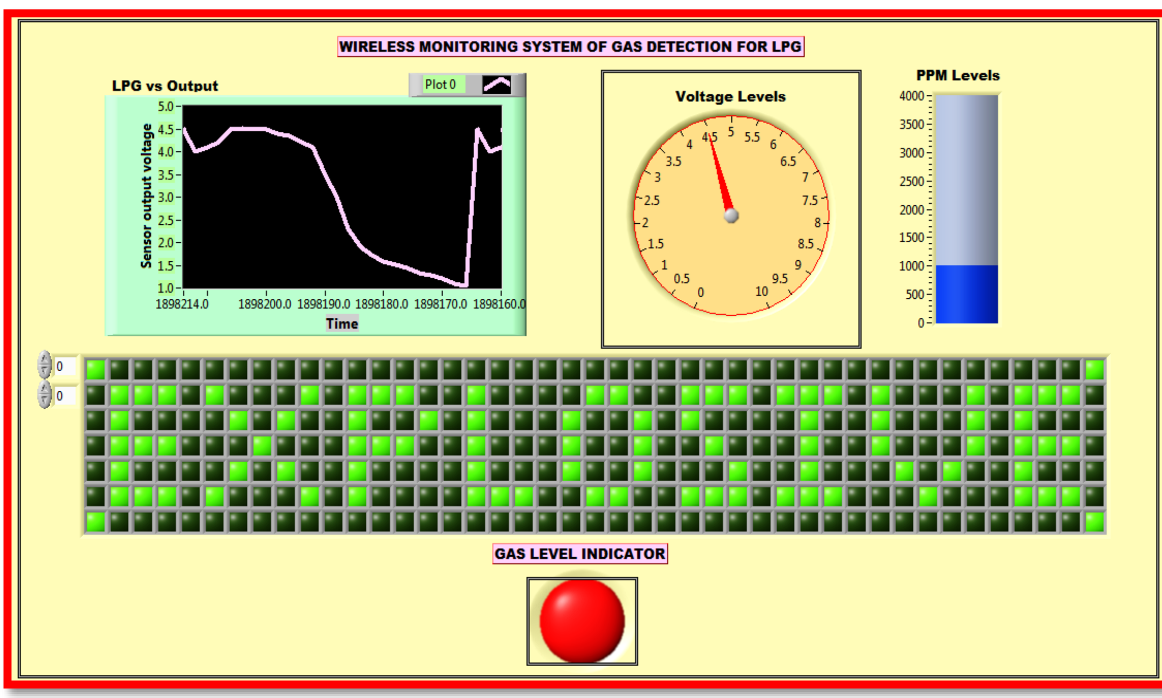


Fig.4.22. Explosive level indication of the gas leakage detection.

The purpose of GUI is to make the system more interactive and facile. The programming structure is shown in fig.4.23.

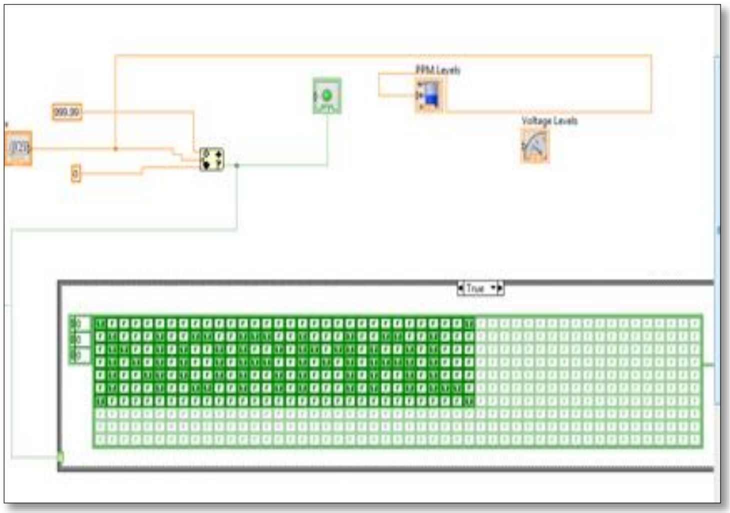


Fig.4.23. Programming of string display rating.

The actual implementation of wireless gas sensing system for four sensor nodes is done in LabVIEW is shown in fig.4.24.

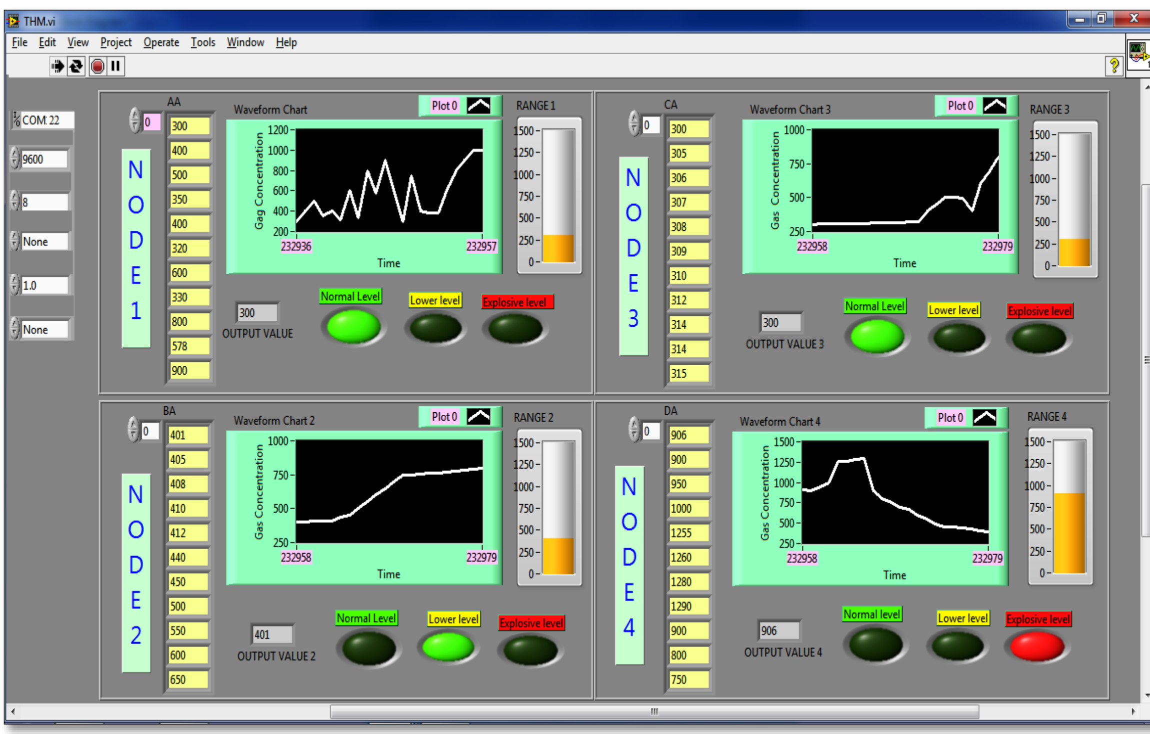


Fig.4.24. Actual monitoring of wireless gas sensing system for four sensor node.

4.7 Internet Control of LabVIEW

Today there is an enormous interest in the development of gas monitoring systems for application in the gas leaks, detection of harmful gases in mines, home safety, exhausts gas monitoring, etc. In all these fields, a key matter is the need of the flexible and practical virtual instruments, a way to easily expose the gas sensors to hazardous levels of gas concentration. This section presents a conceptual architecture for a versatile, flexible, cost efficient and portable system for monitoring the gas presence in the air. The software platform in terms of virtual instruments is developed under LabVIEW programming environment for internet connectivity to cover a large monitoring area.

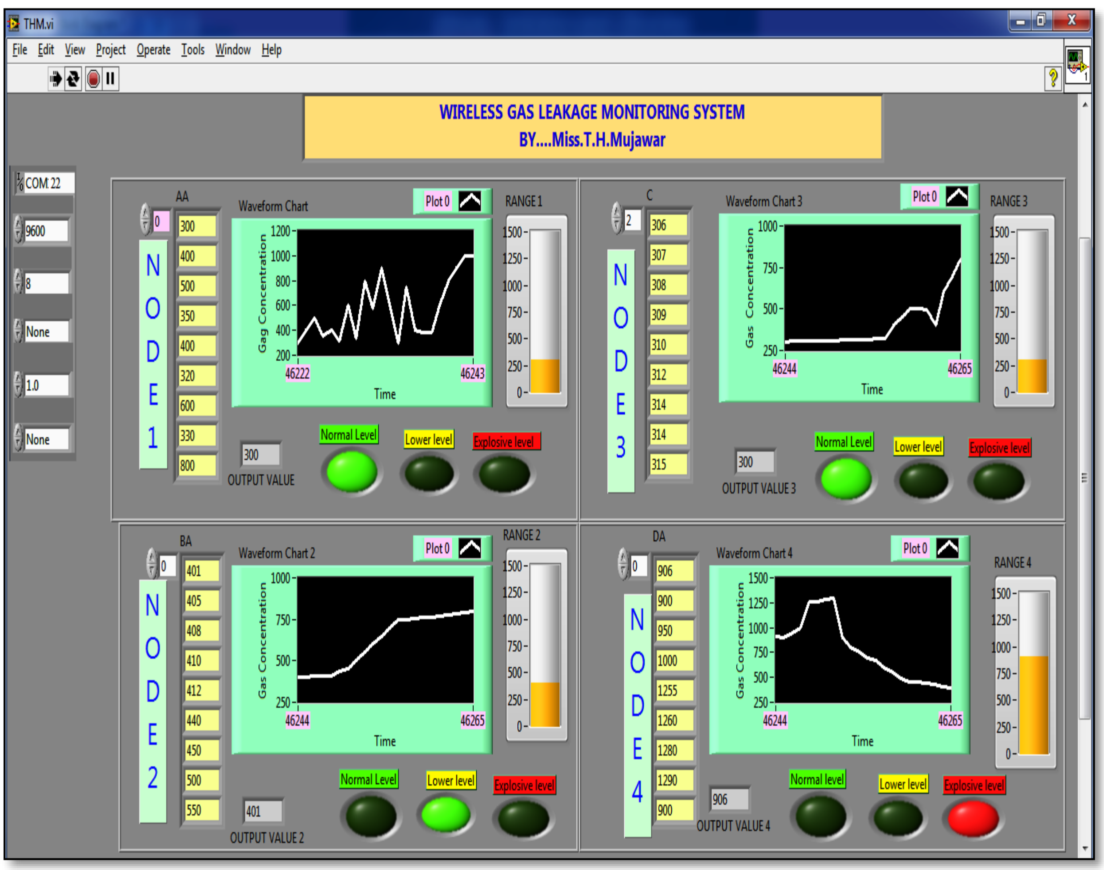
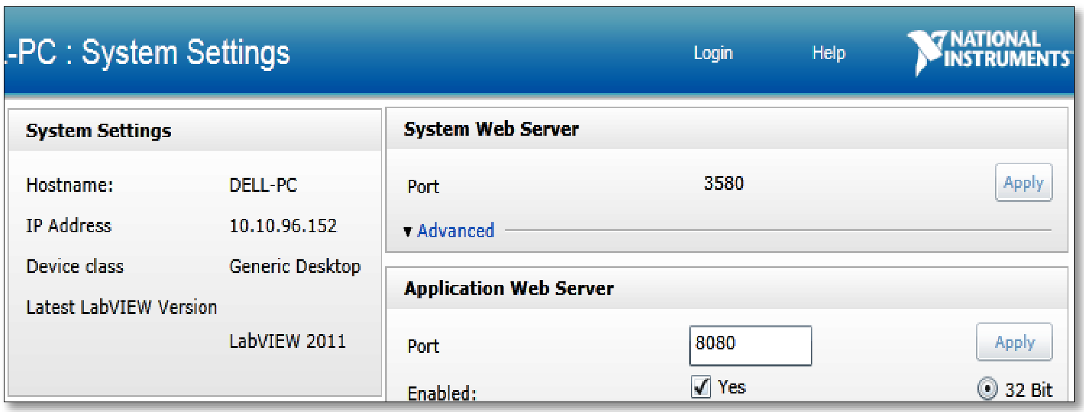


Fig.4.25. LPG gas leakage monitoring system.

The signals from the different sensor nodes are sent to the LabVIEW. If the IP address of the PC enters into web then it gives the page based on front panel.

Remote monitoring is done by a LabVIEW front panel by accessing the web server and this system is controlled by using web publishing tool. This tool converts the front panel into HTML web page based on the parameters given in the program. The GUI which is displayed on the web server is as follows (fig. 4.25). We have built a simple VI that monitors the wireless LPG gas leakage detection system. We launched this application in the internet and monitored it remotely and controlled it automatically. For launching this application in the internet, we must have to configure the web access. After accessing the web configuration, we get the port address and IP address as follows.



By default, LabVIEW has port address of 8000.

In LabVIEW, we can access the other remote panel server and all other IP addresses which we want by enabling this setting in web publishing tool.

The document URL obtained through LabVIEW is shown below. By pressing Connect button and then OK. The webpage will be published and the browser will open.

The document URL obtained from the LabVIEW page is **http://dell-pc:8000/THM.html.**

Figure 4.26 shows the data monitoring system in the internet browser. The display of wireless gas monitoring on the internet server will give an advantage to user for monitoring the building or industrial air environment quality at remoteness continuously.

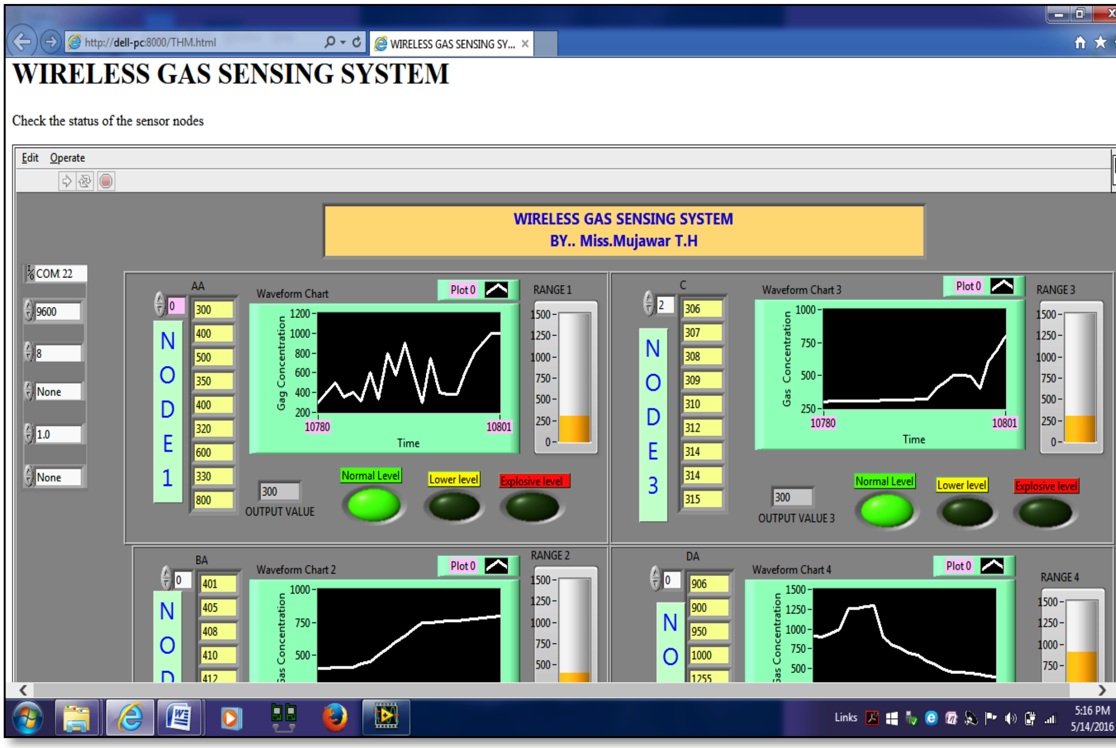
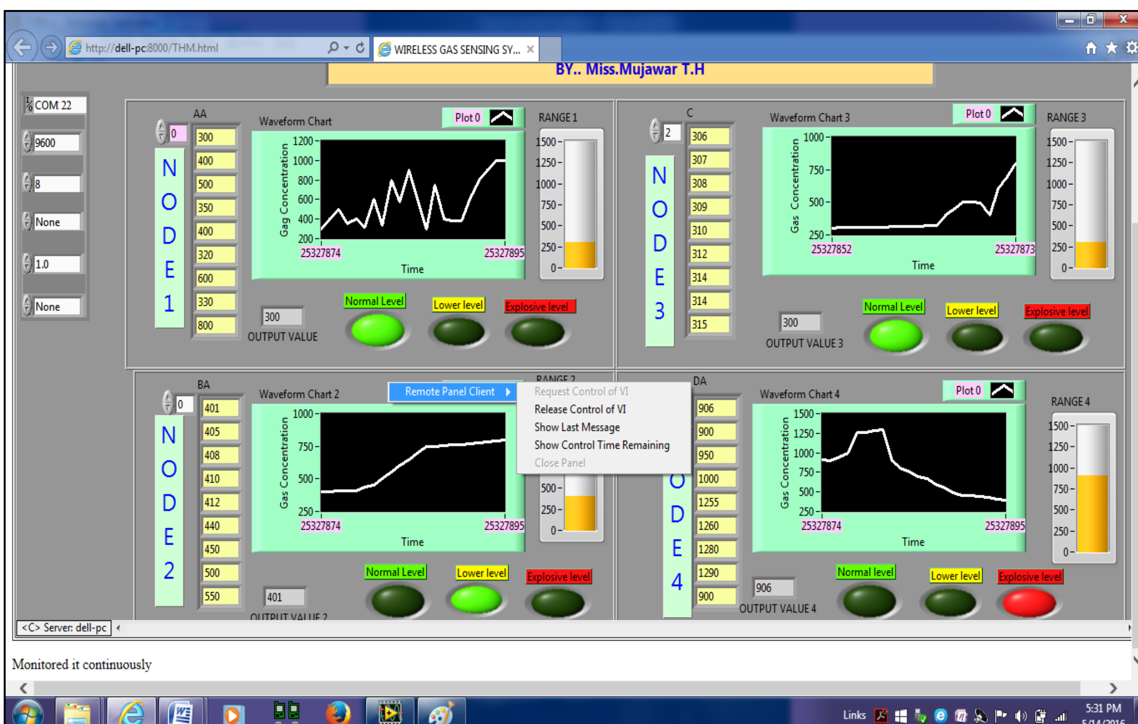
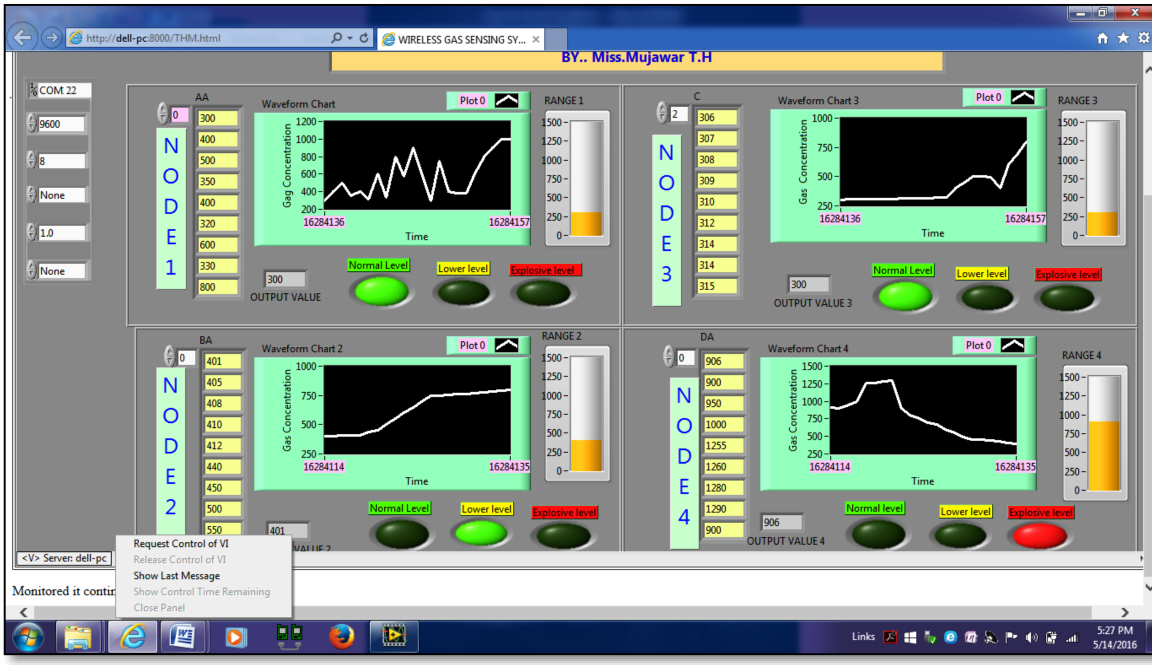


Fig. 4.26 The data monitoring system in the internet browser.

We can access the remote panel client and also request control can be done on online. The following web display images show these results respectively.





4.8 Implementation of the Wireless Sensor Networks to Control the Hazardous Gas Leakage Area

The design of a wireless LPG leakage monitoring system is proposed for home safety. This system detects the leakage of the LPG and alerts the consumer about the leak by SMS and as an emergency measure, the system will turn off the power supply, while activating the alarm. Liquid petroleum gas is generally used in houses and industries. In homes, LPG is used mainly for cooking purposes. This energy source is primarily composed of propane and butane which are highly flammable chemical compounds.LPG leak can happen, though rarely, inside a home, commercial premises or in gas powered vehicles. Leakage of this gas is dangerous as it enhances the risk of explosion. An odorant such as ethanethiol is added to LPG, so that leaks can be detected easily by most people. Our work aims at the designing of a system that detects gas leakage and alerts the subscriber through alarm, sending SMS on user mobile phone and turning off the gas supply valve as a primary safety measure. The system more like a First Aid, automatically uses a solenoid valve for shutting off of the gas valve before calling for help via visual display and audible alarm to those within the environment. The system

prototype is constructed and when a small amount of LPG is leaked near the system, the system sensor detects the leakage and sends the SMS to housemates and activates the alarm and switches on the exhaust fan and prevents the flow of gas using a solenoid valve.

4.9 The Control Unit Circuit Diagram

The control unit receives a signal from the gas detector sensor and then sends signal to the solenoid valve drive unit and then activate an alarm. It also displays the status of the gas concentration on a GUI and also displays it on the web browser. Shown in fig.4.27 (a) is the control unit circuit diagram, using solenoid valve.

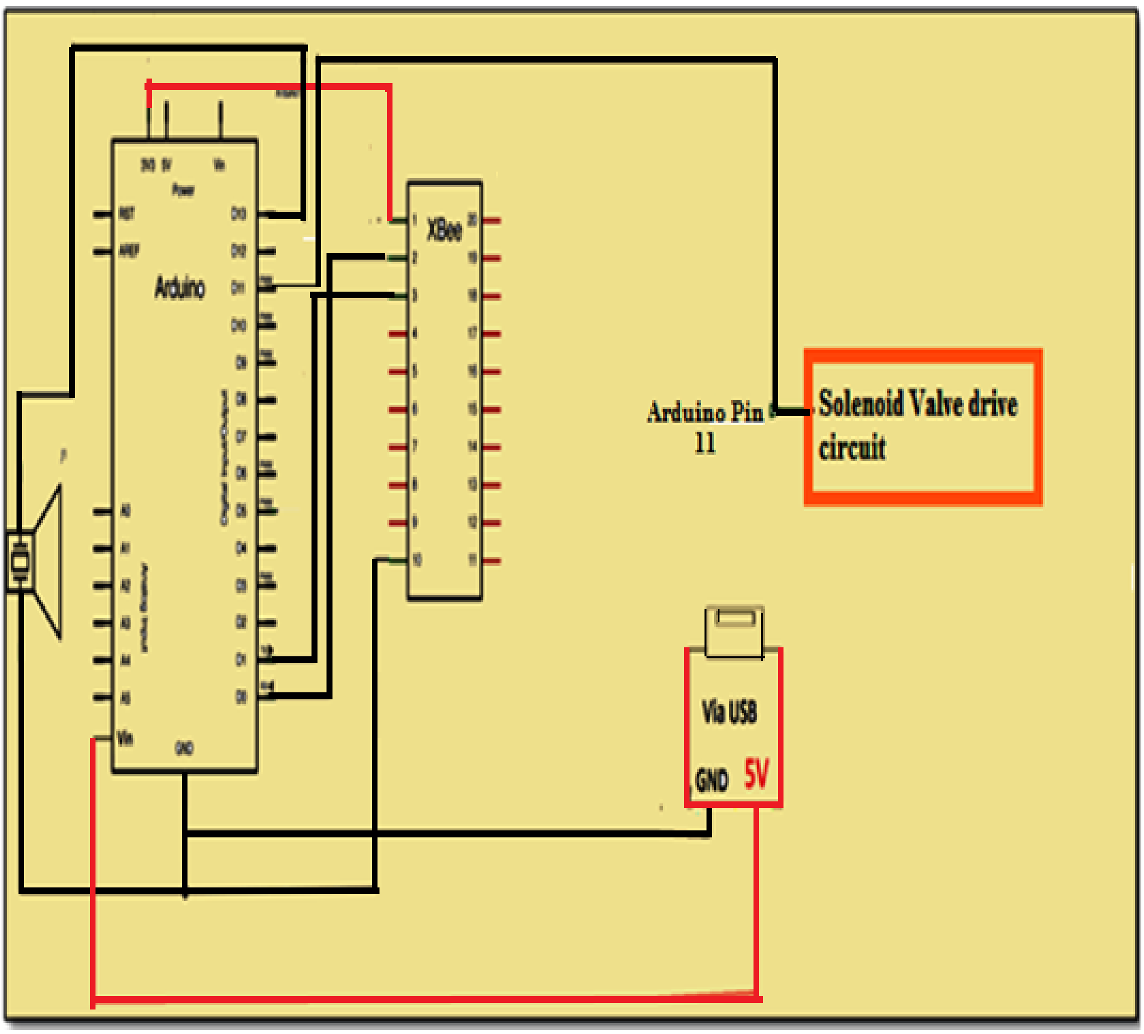


Fig.4.27 (a) Control unit circuit diagram using solenoid valve.

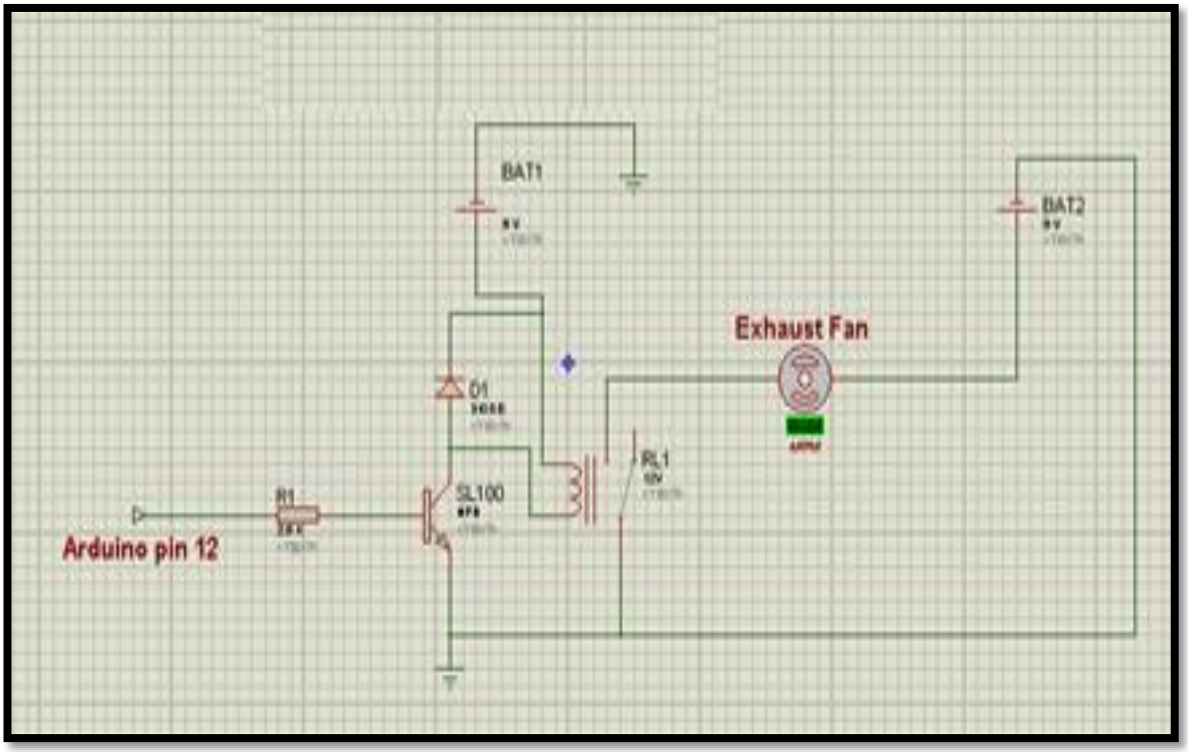


Fig. 4.27 b): Using exhaust fan.

From the circuit diagram, the control circuit is implemented with an Arduino UNO microcontroller which acts as a co-ordinator node. The signals from the MQ-6 gas sensors are coming from various sensor nodes to co-ordinator node. The arduino pin 11, 12, 13 are used to drive the solenoid valve drive control, exhaust fan and the buzzer alarm. When the concentration of gas rises above that of threshold level in the microcontroller, the microcontroller sends a signal to the solenoid valve drive unit to close the solenoid valve so as to shut OFF gas supply and also activate an alarm to alert that there is gas leakage and exhaust fan turns ON (fig.4.27 (b)) emitting the gas outside leading to rarification of the gas respectively.

4.9.1 Control using solenoid valve

Figure 4.28 shows the solenoid valve. It has two key parts - solenoid and valve. It is the electromagnetic valve for gas control by stopping or running the current through it by means of which opens or closes the valve.

a) Specifications

1) 9-24V DC operations

2) Push or pull type with 5.5 mm throw

3) DC coil resistance: 100 ohms

4) 5 Newton starting force (24V DC).

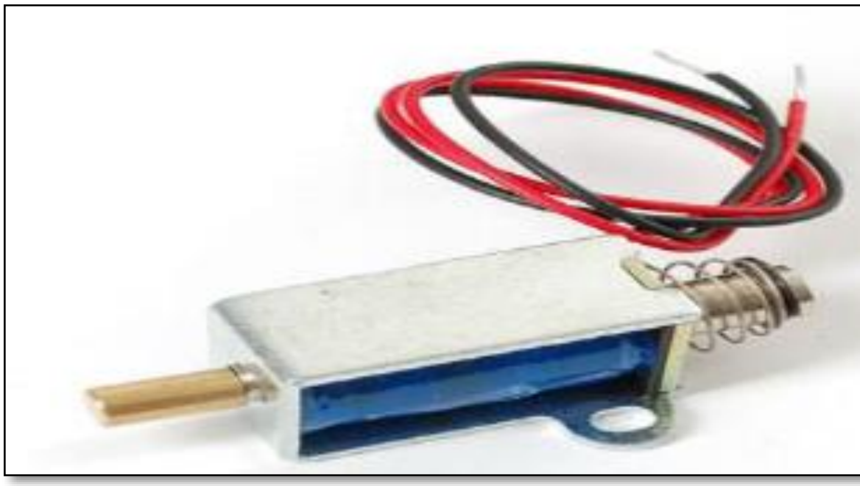


Fig.4.28. The solenoid valve.

b) Solenoid valve drive circuit

The solenoid valve drive unit controls the opening and closing of the solenoid valve which controls the flow of gas from the supply to the point where the gas is being used. The solenoid valve drive receives signal from the control unit and carries out the appropriate action. Fig.4.29 is a solenoid valve drive unit circuit diagram. Using the arduino to control the solenoid valve is simply a case of setting a pin high for the appropriate amount of time. Both the arduino and the solenoid works at a different voltage, so we cannot directly connect the two. In this case, a SL100 transistor is used as a bridge. The signal from arduino Pin 11 is applied to the base of BJT transistors Q1. Resistor R3 is the current limiting resistor which is used to bias the base current of transistor Q1. At the maximum rating of the SL100 (from datasheet) the value of components are determined.

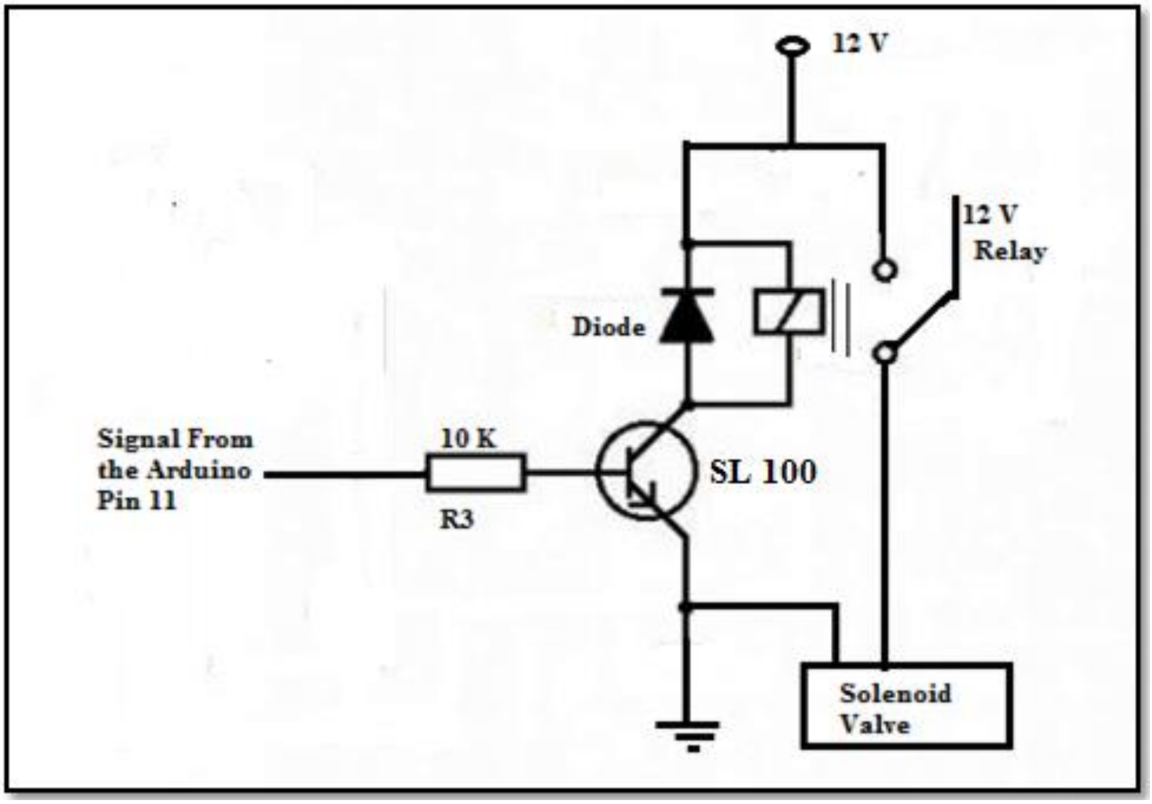


Fig.4.29 Solenoid valve drive circuit.

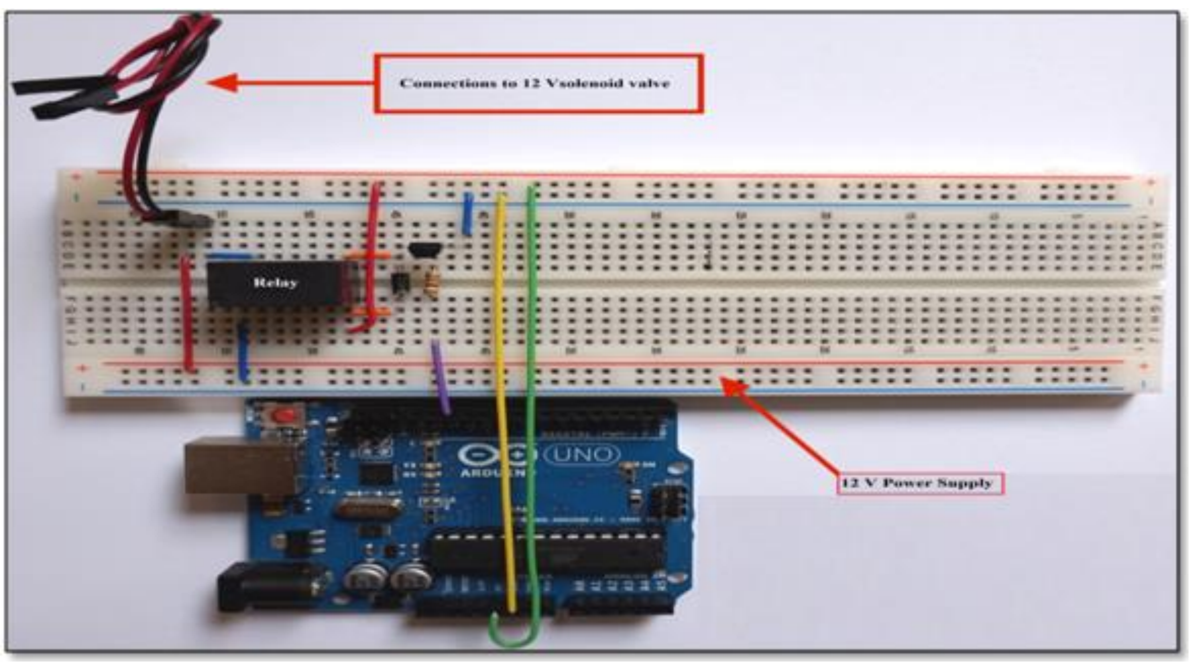


Fig. 4.30. Arduino connection to solenoid valve.

The arduino connection to solenoid valve is shown in fig.4.30.

The programming is done by using an arduino IDE as below (fig. 4.31).

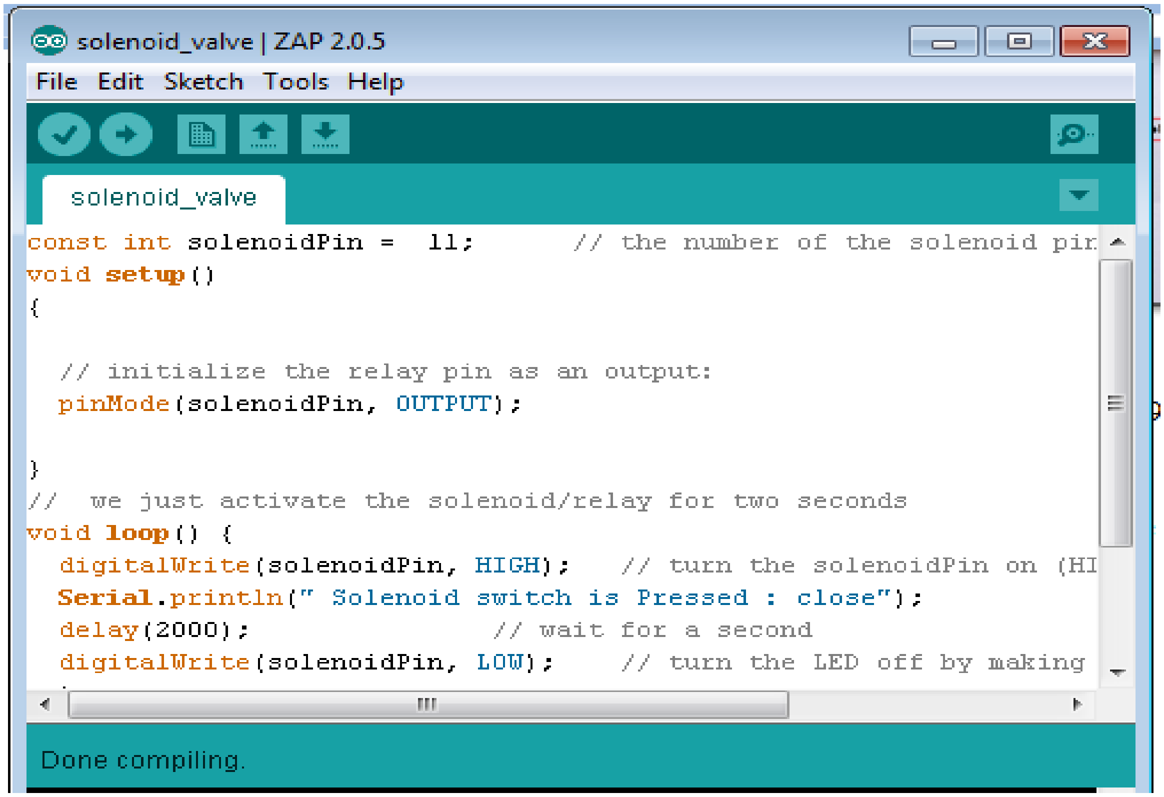


Fig.4.31. a) An Arduino programming for solenoid valve.

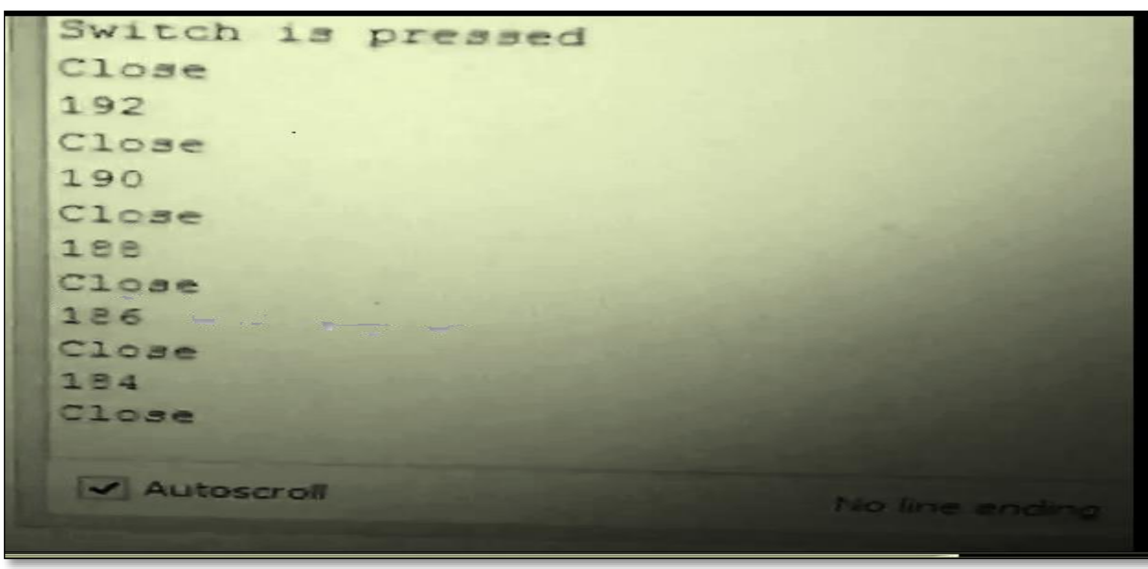
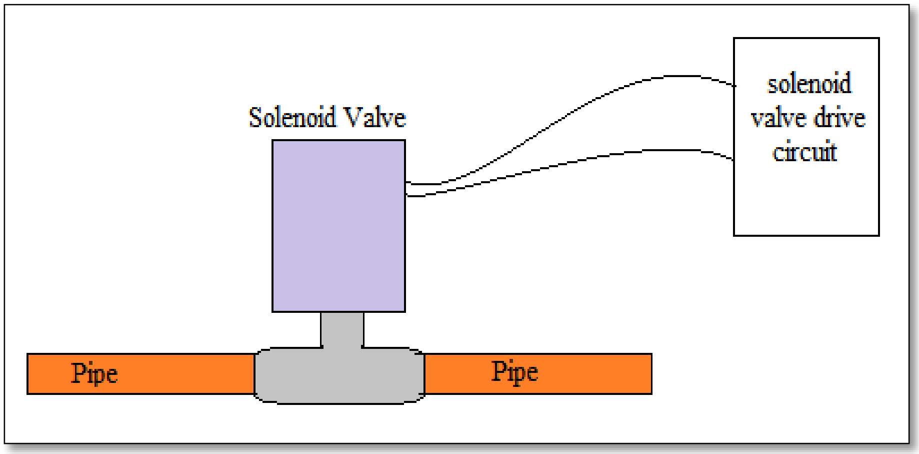


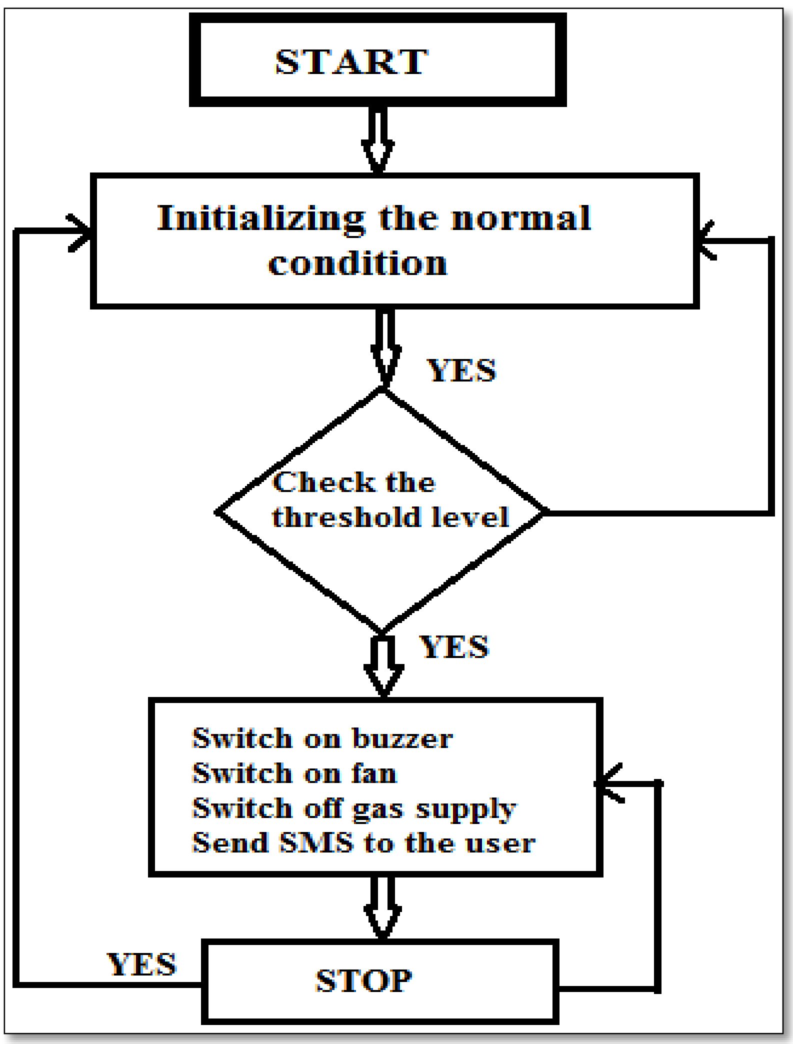
Fig.4.31.b) An Arduino with serial monitor window result.

The solenoid valve setting to gas cylinder regulator pipe is shown below. The solenoid valve gets energized after current flowing through the drive circuit, when

the signal arrives from the controller. As gas concentration goes beyond the explosive level, it shut off the gas flow through valve.



c) The flowchart of the control algorithm



d) Control using fan

Exhaust fan as shown in figure 4.32 is a fan for ventilating an interior by drawing air from the interior and expelling it outside. Fig. 4.27 (b) shows the fan drive circuit. This system needs a system combination with exhaust fan as the precaution step before entering the dangerous level. Exhaust fan will suck out all the air inside the room or building that had been installed with the system to the outside of the building. Therefore, the air quality inside the room will be maintained in the safe air quality. As shown in fig.4.27 (b) the signal from the arduino UNO (co-ordinator node) is applied to the base of BJT transistors Q1. The resistance R1 is current limiting resistor. The design values are selected from the datasheets of SL100.

Fig. 4.32 Exhaust fan.

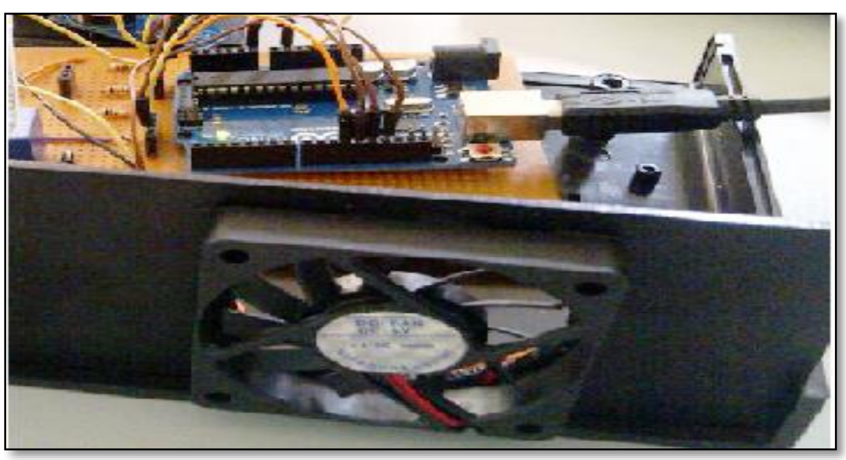


Fig.4.33. Arduino connection to exhaust fan.

An Arduino programming for exhaust fan is done in such a way that, when the gas concentration is below 400 ppm, the exhaust fan is in OFF condition. When the gas leakage level increases beyond the threshold level given in the system, the exhaust fan will be turned ON.

4.10. Testing and Results

Testing was carried out by releasing the LPG into the atmosphere around the sensor. The present system detects the gas leakage and monitors the same and automatically shuts OFF the supply through the gas valve and sounds an alarm.

The table below shows the status of the system as per the type of the leakage.

Gas Concentration	System Status	Voltage Range	Functions Performed		
			Alarm	Solenoid valve	Exhaust Fan
< 400 PPM	Normal level	< 1.5 V	OFF	OFF	OFF
400 PPM-800 PPM	Warning level	1.5 V- 4.2V	OFF	OFF	ON
> 800 PPM	Explosive level	> 4.2V	ON	ON	ON

4.11 Conclusions

Detection and monitoring system for LPG is proposed. When an explosive leak occurs, the system detects the leakage and sends the alert SMS to the end user and activates the alarm and provides the protection circuitry to control the gas flow emission using solenoid valve. Also, precautionary measures (such as activation of the buzzer, exhaust fan, etc.) are taken by the system. The VISA is interfaced to LabVIEW and the data monitoring system is also interfaced to the internet server.

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CHAPTER V

RANGE TESTING OF THE XBEE AND RESULTS

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CHAPTER V

RANGE TESTING OF THE XBEE AND RESULTS

5.1 Introduction

Through our wireless gas sensing system, we built a single-hop XBee network with several XBee wireless nodes where each node consists of a XBee module and an Arduino microcontroller. The arduino consists of a simple open hardware design for a single-board microcontroller with embedded I/O support and a standard programming language; C/C++ language is the main programming language of the Arduino [1]. Communication with XBee modules is done either via an Arduino or via an USB dongle, which is connected to a computer. For a successful deployment of wireless network, we need to evaluate some basic performance parameters such as radio performance (e.g., received signal strength, coverage ranges and link failure probability), packet delays and throughputs. For our system, we focus on the measurement of Received Signal Strength Indicator (RSSI). The range test consists of the effect of the distance, power emitted and disturbance effect of different electronic devices and barriers on the reception of the XBee modules. Many instruments are used in these tests. Some of the tests are repeated to ensure the correctness of the results and reliability. Tools used in testing the range are an Arduino –XBee module programmed to send back a message that is send from a computer using X-CTU. Different configurations and environments were chosen. Normally, a loop back test is performed for the range test [2-4].

5.2 XBee Testing and Configuration

In this measurement, we aimed to study the actual coverage range of the XBee- S2 in real life conditions. For our measurements, we used a loop back test which was performed by X-CTU in order to measure the relationship between received signal strength (RSSI) and the distance for a point to point link. communication between the PC and XBee is an integral part of our system, where

for XBee configuration, monitoring and control of a device, or simply for testing and feedback are of importance. Using Digi's X-CTU software and adapter, interfacing with the XBee is simple for configuration changes, firmware downloads, testing signal strength and communication to your remote devices [5]. In this chapter many configuration settings of the XBee are explored.

5.2.1 XBee testing

In this section, we have explored Digi International's X-CTU software for communication, signal strength monitoring and configuration of the XBee. The XBee connected to the PC using the XBee USB adapter and a remote XBee with power and a loopback are used. For the loopback, DOUT is connected to DIN which will cause any received data to be transmitted back to the PC as shown in figure 5.1.

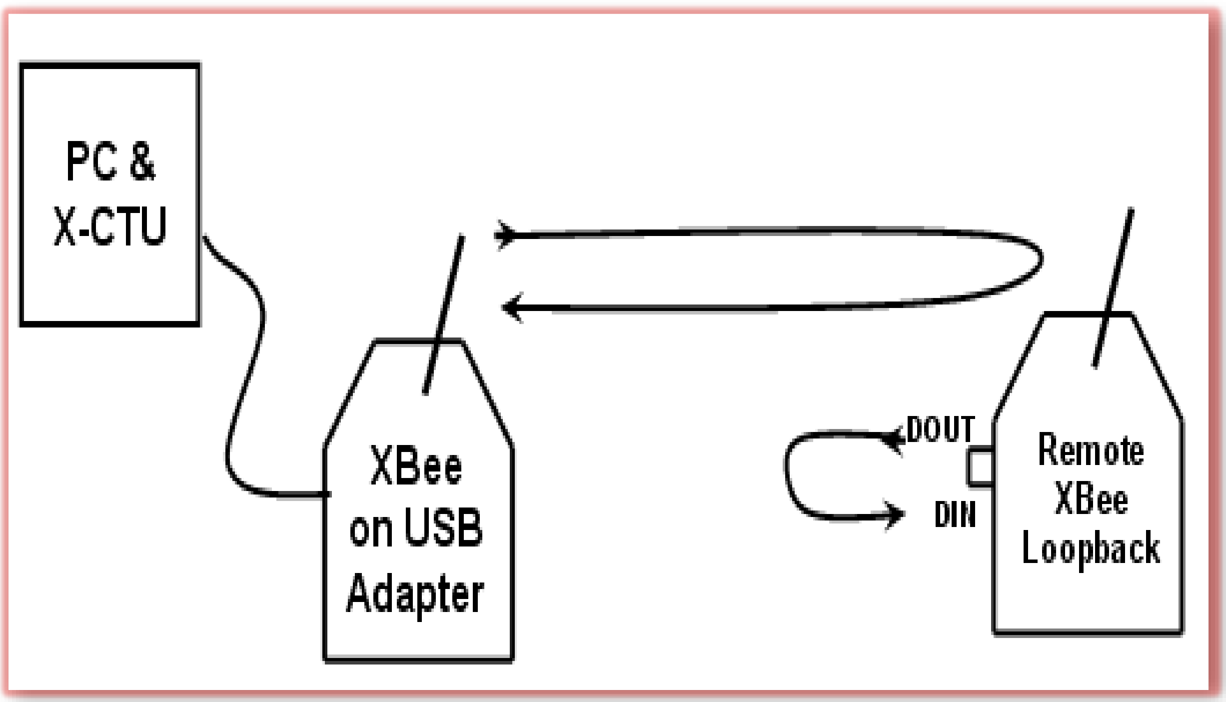


Fig.5.1. XBee loopback testing.

The XBee's used here have on board Tx/Rx LED's and RSSI or ASSOC LEDs. Therefore, there is no need of external LEDs. After powering up, both units have POWER and ON/SLEEP LEDs illuminated and ASSOC LEDs blinking.

5.2.2 Testing of communication between two XBee's

We have tested the communication using X-CTU software as below.

When XBee USB Adapter was connected, we were having one or more COM ports listed as shown in the figure 5.2.

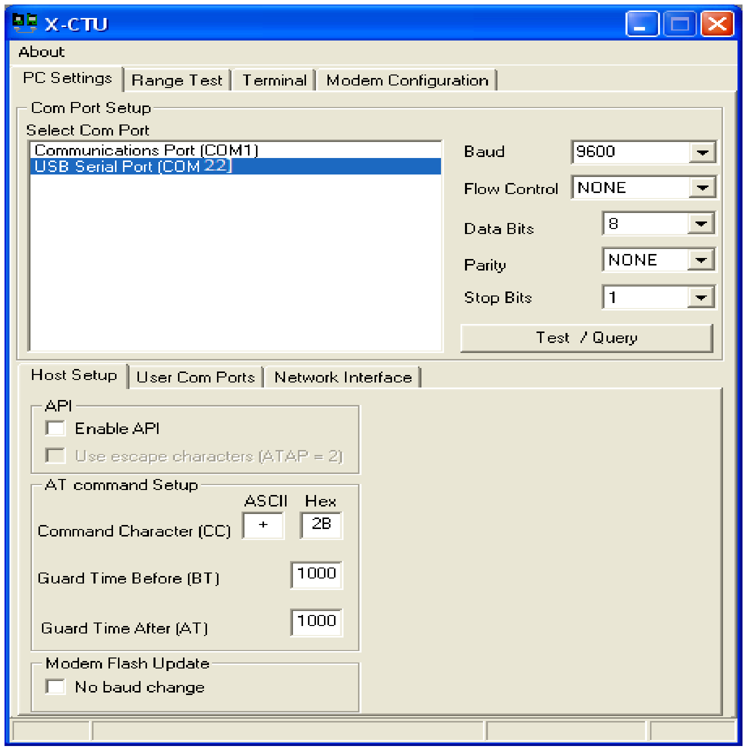


Fig. 5.2.COM port setting of X-CTU.

- ❖ To check the data is send and received using a terminal interface, type **Hello World!** in window area.

The figure 5.3 shows sending data in the blue character and the receiving data in red character.

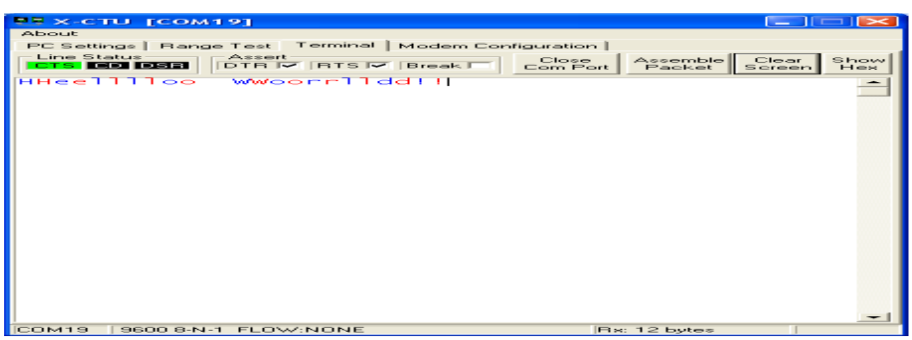


Fig.5.3. X-CTU terminal test.

- ❖ As each character was typed, it was transmitted, looped-back and returned for reception and display.
- ❖ The Tx/Rx LEDs should light on the remote board, blinking rapidly as the data is sent and received.
- ❖ Assembling and sensing of packets are shown in fig.5.4.

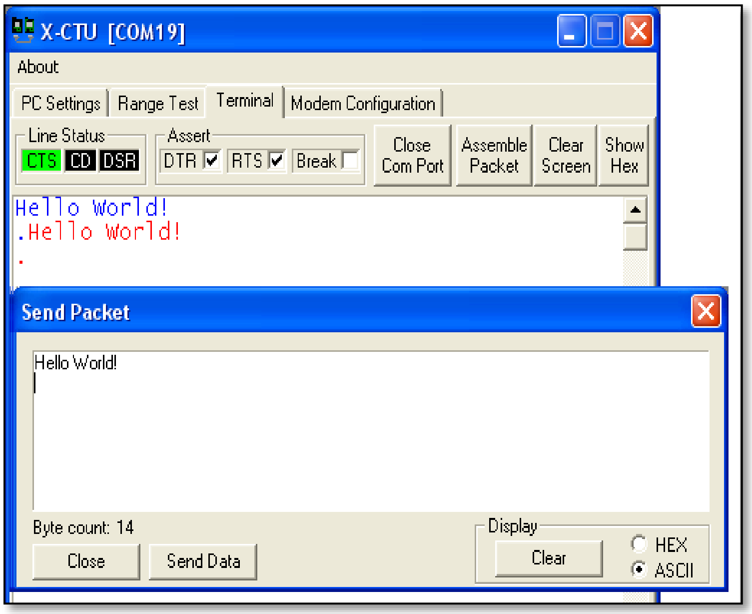


Figure 5.4 Assembling and sending a text packet.

While, it is interesting at this stage to see what would happen if there were two remote XBee modules with loopback. One remote XBee that is transmitting will cause a repeat on the other XBee and back again; the one transmission will be repeated over and over between XBee modules essentially causing a broadcast storm. Because all the XBee modules currently have the same address, by default, they will be sending to each other as well as the base and repeating what they get. Hence, addressing for each XBee is essential.

5.3 Range Testing and Range Test Measurements

5.3.1 Range testing

- ❖ The **Range Test** tab on the software (fig.5.5) is used for XBee signal strength measurements.

❖ Under the vertical **RSSI** letterings, check the checkbox to monitor signal strength (fig.5.6).

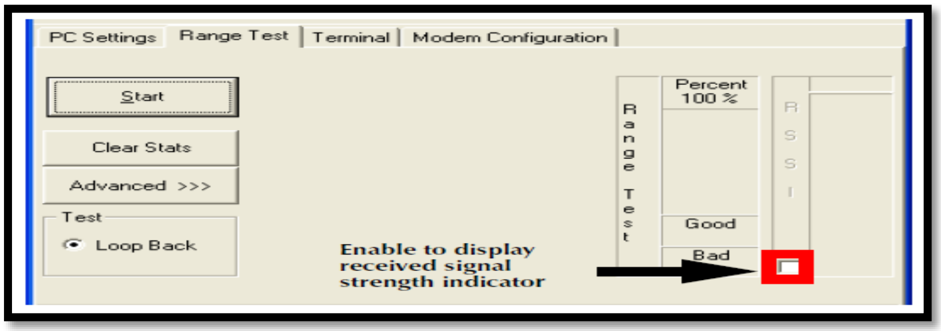


Fig. 5.5.Software setting for range test.

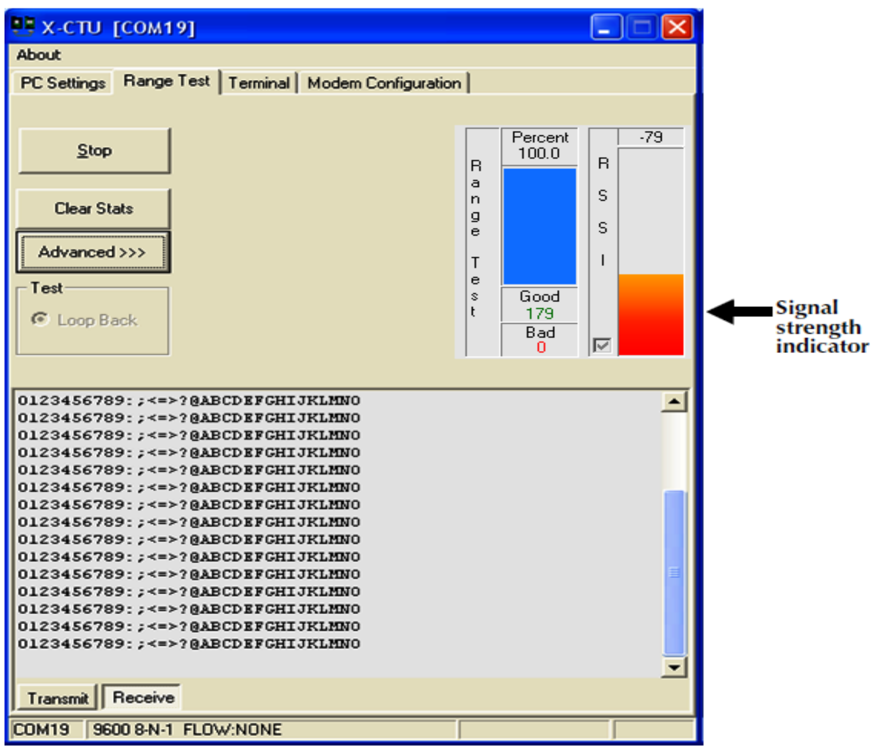


Fig.5.6. Range testing and RSSI monitoring.

The range test runs indefinitely until you click Stop. The percent field indicates true link quality by showing the percentage of successful packet transmission. If the RSSI checkbox is enabled, the signal strength of packets received by the XBee module on the USB interface board is displayed .RSSI is the received signal strength indicator value. This value will be between -40 dBm (the

highest recorded value) and -100 dBm (the minimum sensitivity of the XBee) [6-9]. For our system, the RSSI value lies between -40 dBm and -84 dBm.

The environmental conditions on transmission link were checked as:

❖ The test interference of the signal was checked by placing your hands over it, blocking line-of-sight with your body, placing a metal box over an XBee, or moving the remote XBee to a further location or a different room or floor in the building.

5.3.2 Range test measurements

In this section, we write the data collected in test done at our laboratory with and without barriers [10].

a) Inside the laboratory- no barriers

In this experiment, we have measured the RSSI level when the distance between two XBee modules changes. In actual, we measured the change in the level of RSSI in relation to the change in the distance between the XBee modules [10]. We used a non-line-of-sight (NLOS) setting in the School of Physical Sciences by placing the coordinator node in our laboratory in front of the door and the sensor node inside the room. We increased the distance slowly from the coordinator. In this experiment, the factors which may affect the strength of the signal (such as the Wi-Fi routers and cordless phones) are not considered. [11-12]. Table 5.1 shows the range test for two XBee end devices with different distances between them when there were no barriers in between them. As we see, it is safe only up to 8 m and after that; there is a more packet loss between the two XBee's [10]. The signal strength indication of XBee series 2 was tested using USB to UART convertor connected to it and tested on condition such that they are between the inside the room. Table 5.2 shows the actual value obtained from the X-CTU software on testing the signal strength indicator for XBee modules.

Module 1	Module 2	Distance (m)	Baud Rate	Packet Loss Module 1	Packet Loss Module 2	Barriers	Signal Strength
XBee Router in AT Mode	XBee Router in AT Mode	0	9600	0	0	No	100%
		4	9600	2	2	No	65%
		5	9600	4	2	No	60%
		8	9600	8	4	No	50%
		9.77	9600	42	40	No	40%

Table 5.1. Range test-AT configuration

Distance meters	RSSI dBm
0	-40
4	-67
5	-79
8	-81
9.77	-84

Table 5.2.Observations of RSSI vs. indoor distance for XBee modules.

The fig.5.7 shows a plot of RSSI values in dBm versus distance in meters. The longest detect range for XBee is up to 9.77m and captured RSSI value is -84 dBm. As the distance is increased, signal strength of XBee is decreased.Fig.5.8 shows RSSI indication of XBee module in X-CTU view.

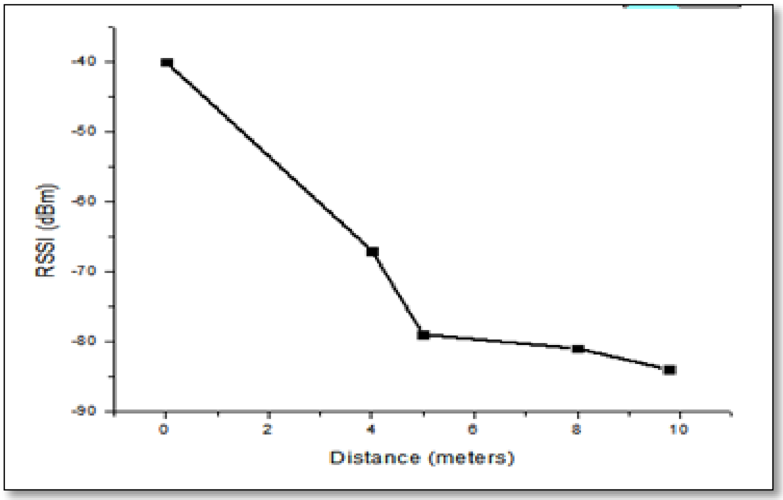


Fig. 5.7. A plot of RSSI (dBm) vs distance (meters).

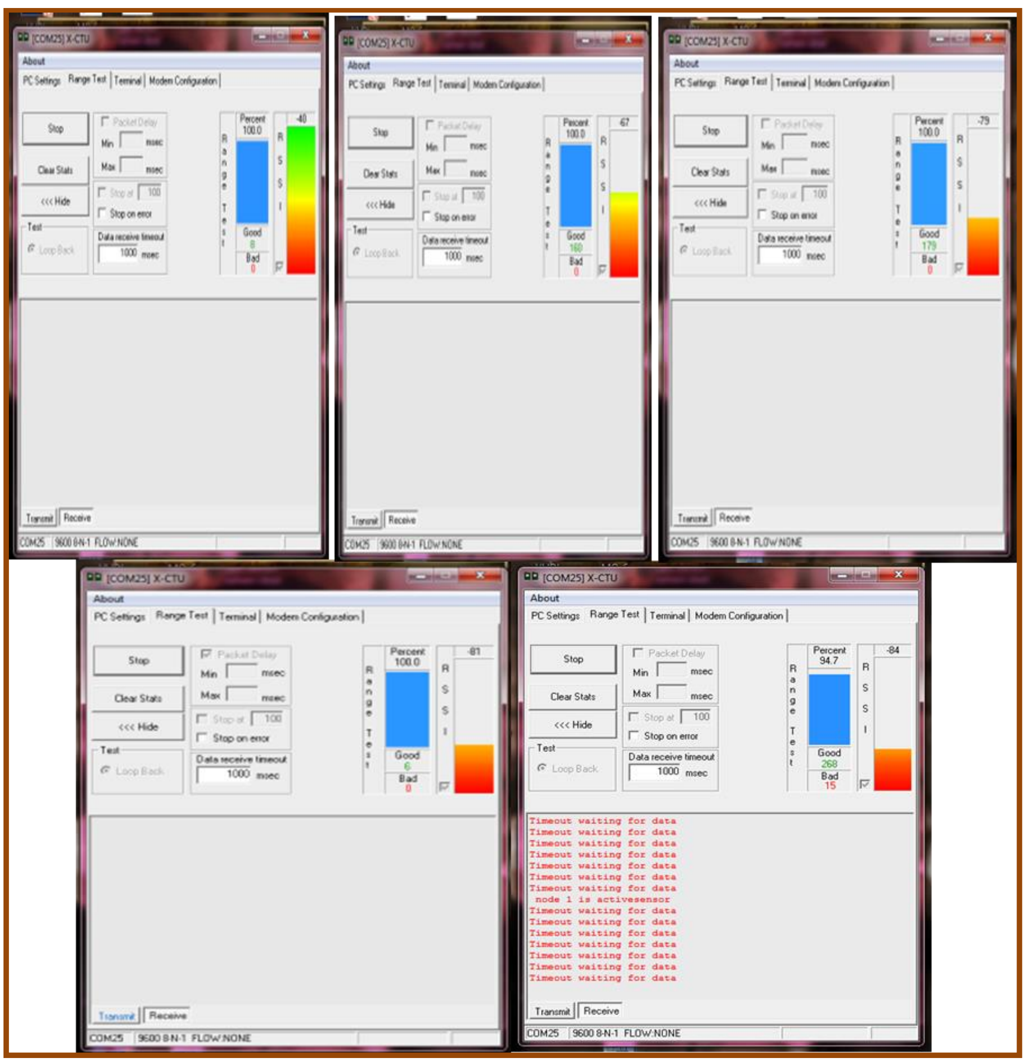


Fig.5.8. X-CTU screen for indoor measurement of RSSI value.

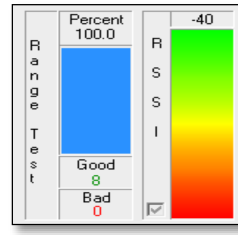
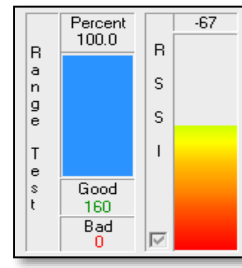
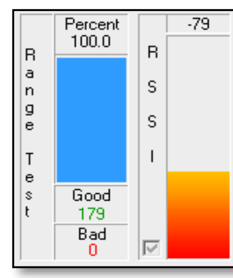
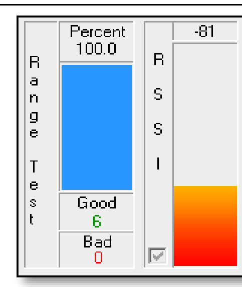
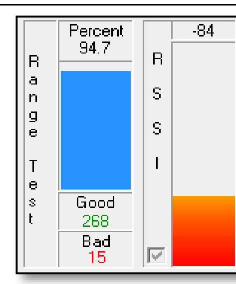
Module 1	Module 2	Distance (m)	Baud Rate	Packet Loss Module 1	Packet Loss Module 2	Barriers	Range
XBee Router AT	XBee Router AT	0	9600	0	0	NO	
XBee Router AT	XBee Router AT	4	9600	2	2	NO	
XBee Router AT	XBee Router AT	5	9600	4	2	NO	
XBee Router AT	XBee Router AT	8	9600	8	4	NO	
XBee Router AT	XBee Router AT	9.77	9600	42	40	NO	

Table 5.3.Range test-AT configurations (without barriers).

The X-CTU is perfect environment for testing the XBee range since we can see the effect of various parameters on the reception. All these effects have been seen for indoor measurement (No barriers) in fig.5.9.

The effect of varying distance on packet loss and range at constant baud rate of 9600 are displayed in table 5.3.

It is observed that, for a constant baud rate of 9600, when packet loss increases the RSSI decreases.

b) Range test with barriers between the two XBee modules-AT configurations

The tables below (5.4 and 5.5) represent the same results, but in table 5.5 the X-CTU is shown.

Module 1	Module 2	Distance (cm)	Baud rate	Barriers	Signal Strength
XBee Router AT	XBee Router AT	100	9600	Wall	63%
		300	9600	Wall and doors	52%
		700	9600	Wall	50%
		900	9600	Wall	45%

Table 5.4. Range test –AT configuration (with barriers).

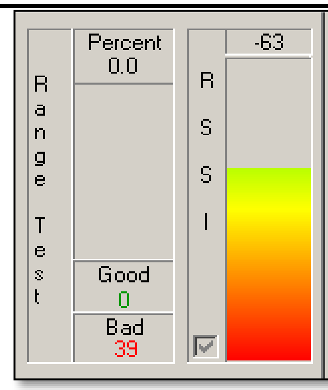
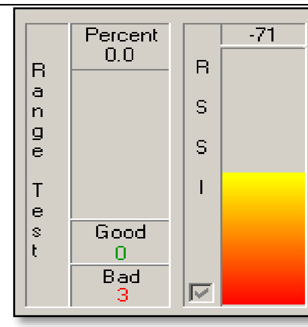
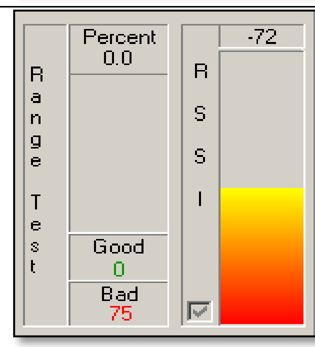
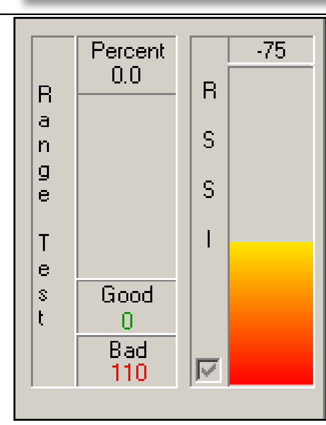
Module 1	**Module 2**	**Distance (cm)**	**Baud rate**	**Barriers**	**Signal Strength**
XBee Router AT	XBee Router AT	100	9600	Wall	
XBee Router AT	XBee Router AT	300	9600	Wall and doors	
XBee Router AT	XBee Router AT	700	9600	Wall	
XBee Router AT	XBee Router AT	900	9600	Wall	

Table 5.5. Range test with barriers between the two XBee - AT configurations.

It appears that signal strength decreased from 63% to 45% when the distance was increased from 100cm to 900 cm. This is shown in fig 5.9[10].

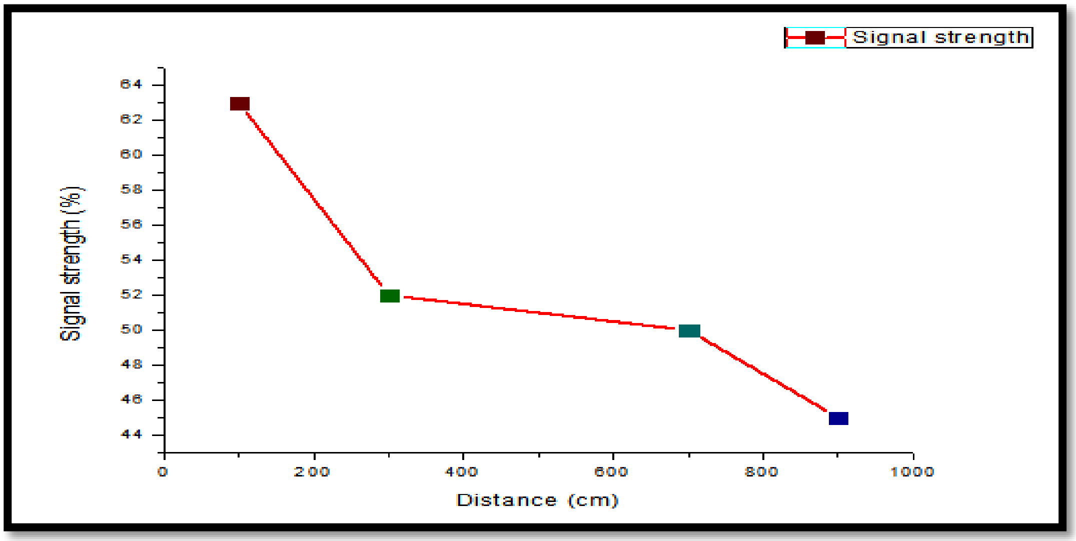


Fig. 5.9. Signal strength vs. distance.

5.4 Results

For the Range test measurement, most of the collected data are based on AT mode. The API mode was not possible to use in the range test because it is complicated, requires more computers and more observations and also arduino works just fine in the AT mode. The fact that the module's sender is consuming the same amount of power in sending one byte in different mode makes it sure that the results collected from AT mode could be used in understanding API Mode also. The sender hardware is a separate part of the XBee that works always in the same way. There is only one configuration which makes a difference in sending, that configuration is the power send by the module. The only difference is that, when and how long the microcontroller inside the XBee module uses the sender part of the XBee hardware?

A range test is affected by many parameters; from the simplest configuration to the complex conditions. This section will make a comparison between each result to find out the best environment and configuration for XBee

communication. It aims to find out a reliable communication between the different XBee modules.

5.4.1 Maximum range reception

We used different distances depending on the environment and XBee module's position. This is represented in fig.5.10 when no barrier is isolating the two XBee modules.

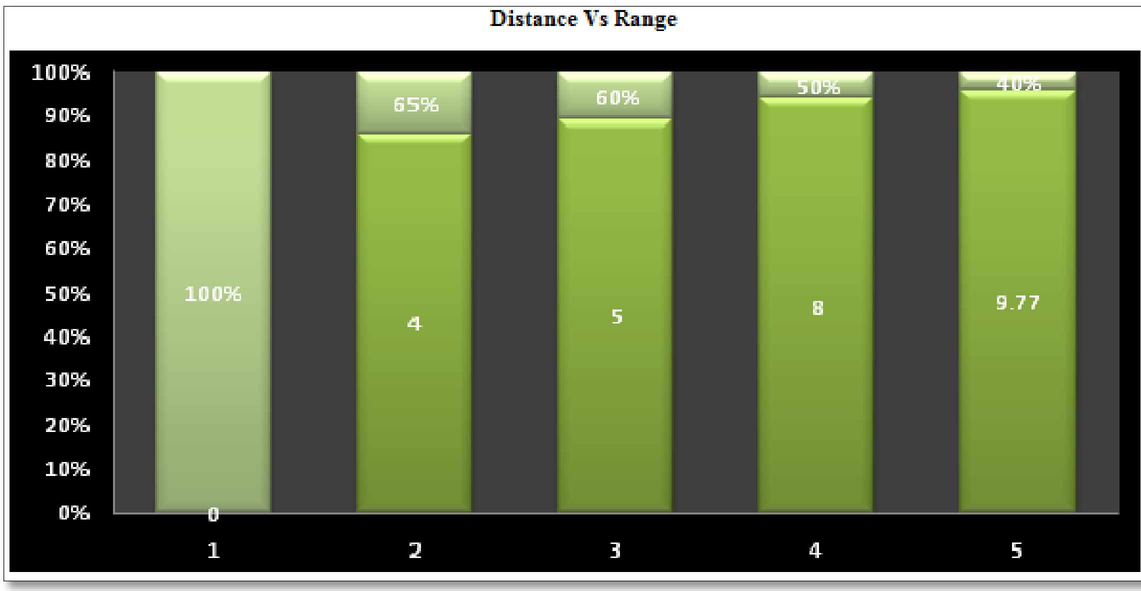


Fig.5.10.Effectof distance (in m) on the reception.

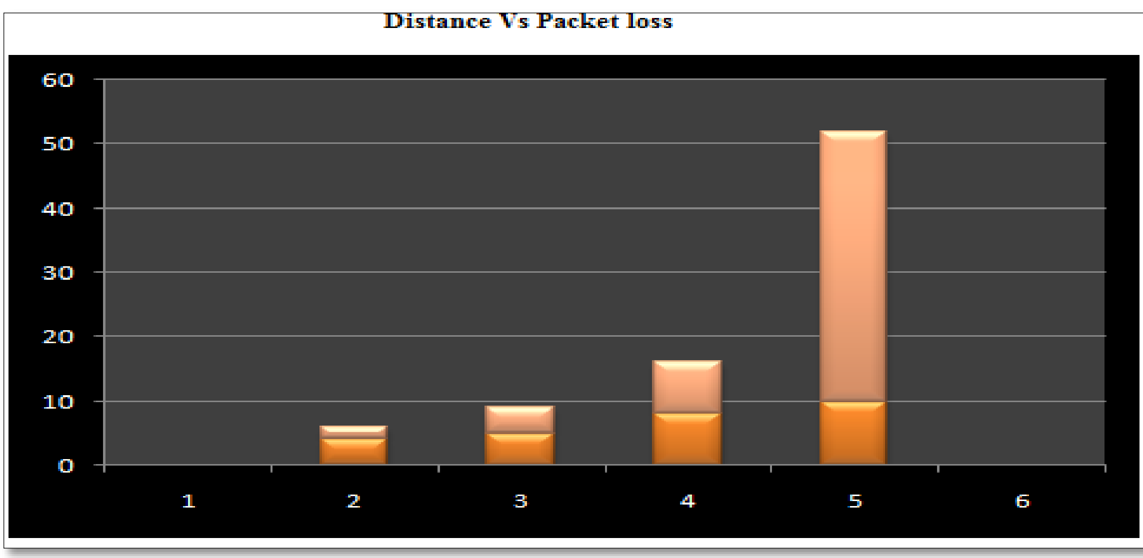


Fig.5.11Effectof distance (in m) on the lost packet.

5.5 Conclusions

The loopback test is an excellent means of testing communication and various configurations. The XBee has a multitude of configuration settings to deal with addressing, interfacing and input and output controls. Using X-CTU, interface allows range testing with loopback, modem configuration and a terminal window for communication, testing and configuration. We measured a relationship between RSSI and distance for a point-to-point link in non-line-of-sight (NLOS) environment. The secured range is about 9.77m. Up to 8 m distance (without barriers), there will less packet loss.

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CHAPTER VI

SUMMARY AND CONCLUSIONS 185

CHAPTER VI
SUMMARY AND CONCLUSIONS

The recent proliferation of small and low-powered hardware platforms that integrate sensing, computation and wireless communication has led to the widespread interest and utility in the design and development of wireless sensor networks (WSN). Such networks have key role applications in a variety of sectors such as medical, industry, military, defense, surveillance, home, etc. Wireless sensors allow otherwise impossible sensor applications, e.g. monitoring dangerous, hazardous and unwired remote areas and locations. The technology provides nearly unlimited installation flexibility for sensors and increased network robustness. Furthermore, wireless technology reduces maintenance complexity and costs. WSN'S allow faster deployment and installation of various types of sensors because many of these networks provide self-organizing, self-configuring, self-diagnosing and self-healing capabilities to the sensor nodes. Some of them also allow flexible extension of the network. Most wireless sensors have signal conditioning and processing units installed at the location of the sensors and transmit signals in the digital form. As a result, noise pick-up becomes a less significant issue. Moreover, since wire connections are deleted from the transreceiving processes, reliability of the signal transmission and receiving is enhanced.

On investigation, it is found that various wireless standards have been established. Among them, the IEEE 802.15.4 (ZigBee) are used more widely for measurement and automation applications. These standards use the instrumentation, scientific and medical (ISM) radio bands. The 2.4 GHz band has a wider bandwidth that allows more channels and frequency hopping and permits compact antennas.

The literature survey showed that, most of the research work has been carried out on gas leakage detection using wired networks. However, wired

sensors and monitoring systems, have many shortcomings**:** a long deployment time, high maintenance cost, dependence on cable telemetry systems, the inability of cables to resist to various damages, as well as large demand in cable supplies. In addition, in remote places, power supply may not be available to implement the monitoring system. Therefore, the present research work was carried out using a WSN to replace incompatible wired network systems. Moreover, the advanced microcontrollers with low power consumption are available to make smart WSN nodes. Taking the above facts into account and considering out laboratory limits, it was proposed to design and develop a system that would be able for reliable communication without the use of wired instrumentation and process control. Accordingly, we have chosen a system, ”Development of Wireless Sensor Network for Hazardous Gas Leakage Detection and Alert System**”,** the objectives of which are to design and develop a suitable system and methodology that can detect presence of a natural LPG gas and send SMS alert to the end user. The design of system being dynamic, monitoring and controlling is also of importance. The system was designed and implemented for the detection of a natural LPG gas. The results of implementation are interpreted adequately. In actual, we have proposed the deployment of ZigBee technology to ensure wireless communication needed to establish a Wireless Sensor Network. To emphasize the ZigBee technology, an architectural details regarding ZigBee device and its programming are extensively studied and given in chapter II .On comparative studies of various wireless technologies, it is found that the ZigBee technology is most suitable and plays a commendable role in the development of Wireless Sensor Network [4-6].According to the architecture; there are two groups of ZigBee devices; the ZigBee series 1 and ZigBee series 2. For our studies series 2 devices were employed. Employing a highly sophisticated IDE, “The X-CTU”, the ZigBee devices are programmed in the desired mode. Therefore, the salient features of this IDE have been studied and understood thoroughly. The programming tool, “XBee

configuration and test utility” provided by the Digi corporation was used to configure the ZigBee devices in either sensor node or co-ordinator ode configurations. Our WSN has four sensor nodes and one co-ordinator node. Various parameters of this ZigBee are configured. The process of configuration is elaborated in third chapter. All these devices are configured in ultra low power mode.

As pointed out earlier, wireless gas sensing system comprises of sensor nodes designed for collecting gas leakage data and these nodes depict the use of an embedded technology, wherein both hardware and software have equal significance. The hardware for WSN node is designed and its issues are discussed in chapter II. It is able to measure the leakage of LPG gas in the industries, chemical plants, kitchen, etc. The design of the sensor node and co-ordinator node are studied separately. Also, the basic study of an arduino GSM shield is described in detail.

The gas leakages in households through the word as CNG and LPG are very commonly used domestic gases that cause fatal accident during the leakage of the gas. As in most cases, these gases are odourless making detection impossible for human olfactory senses. Thus this system describes LPG gas leakage detection, alert, monitoring and controlling. On extensive studies of different LPG sensors, it is found that, the MQ-6 sensor is very low cost sensor, which helped to reduce the cost of the WSN nodes and hence that of the WSN. The calibration of the sensor is successfully done and implemented. Monitoring of the system is done using LabVIEW tool.

The computing is the main part of the WSN node and is wired about an arduino nano microcontroller. This microcontroller is having on chip analog to digital converter with 10 bit resolution. To realize autonomous operation, the WSN nodes are powered with 12 V DC rechargeable batteries. Thus, the WSN nodes are designed and the results of implementation support the preciseness and

reliability of the hardware designed. The circuit is wired on a PCB designed in our laboratory itself (home made). The chapter III deals with the software development of our wireless gas sensing system. The present system uses XBee for wireless communication; therefore, the firmware should cover the function of wireless communication. The co-ordinator node is interfaced to the laptop and this develops an effective GUI for it using a LabVIEW tool. This chapter is also devoted to the discussion on the development of firmware for the WSN nodes and co-ordinator node.

The chapter IV is devoted to the implementation of WSN to monitor the hazardous gas leakage detection. It describes the complete WSN node designed for wireless gas sensing system. To demonstrate the gas leakage data on the monitor of the co-ordinator node, a smart Graphical User Interface (GUI) is developed in NI's LabVIEW tool. Moreover, since the system is designed for measurement of the combustible gas leakage, calibration of the sensor is an essential task. After calibration, the nodes are ready for implementation to the design system. Then the WSN system is established and implemented. The results of implementation are described at length. For interfacing the data transfer by ZigBee in the LabVIEW, a required Virtual Instrument Software Architecture (VISA) configuration serial port is described in detail. The GUI created is displayed on the web browser using the web publishing tool. Our system (WSN) works in star topology. The GUI is also facilitated to store the data in real time. The values of parameters, collected by WSN nodes, are described graphically. This chapter highlights also the control of gas leakage at where leakage happens. This system detects the leakage of the LPG and alerts the consumer about the leak by SMS and as an emergency measure, the system will turn off the power supply while activating the alarm. The system is more like a First Aid, automatically uses a normally closed solenoid valve for shutting off of the gas valve before calling for help via visual display and audible alarm to those within the environment. Also, to turn on the exhaust fan, Arduino

programming for exhaust fan is provided in such a way that, when the gas concentration is below 500 ppm exhaust fan is in off condition. When the gas leakage level increases beyond the explosive level, the exhaust fan turns on automatically. The required drive circuit for solenoid valve and exhaust fan are also described in this chapter. The arduino interfacing to solenoid valve and exhaust fan are also described carefully in this topic.

Chapter V was aimed to study the actual coverage range of the XBee- S2 in real life conditions. For our measurements we used a loop back test which is performed by X-CTU in order to measure the relationship between the Received Signal Strength (RSSI) and the distance for a point to point link. Communication between the PC and XBee is an integral part of our system. Use of Digi's X-CTU software and adapter interfacing with the XBee are simple for configurable changes, firmware downloads, testing signal strength and communication to your remote devices. In this chapter, many configuration settings of the XBee are explored. The relationship between RSSI and distance for a point-to-point link in a non-line-of-sight (NLOS) environment is successfully carried out. The range tests of sensor nodes with and without barrier are successfully carried out and studied. The effects of distance on the range are also elegantly studied and explored.

It is concluded that, as per the objectives, the Wireless Sensor Network system is successfully designed, developed and implemented to monitor and control the LPG gas leakage. There are various types of projects using the similar ideas in different fields of application. However, this system has many fold useful features compared to others, e.g., 1) Monitoring system is developed using a LabVIEW GUI, 2)ZigBee transceiver is used to monitor the gas concentration, 3) Alarm system built by using buzzer to alert the workers, 4) In the autonomous control ,system triggers the exhaust fan in order to ventilate the dangerous gases in the room as well as auto shuts down the gas supply upon the leakage happens

and5) This system is built for the purpose of life-saving that many people in a wide range of industries rely on the alert to them.

Future Implementations

1. The LPG gas release/detection alarm system safety features can also be improved by adding another function to check the sensor’s condition in case the sensor is not working properly or if the sensor’s calibration has been displaced/ deliberately changed.
2. In near future, our motto is to add automatic windows opening system application when the gas leakage is detected within the room / home.
3. To implement android apps.

INDIVIDUAL PROFILE

[Miss. Mujawar Tabbsum Hanif]

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1. Personal Information

Name:	**Mujawar Tabbsum Hanif**
D.O.B:	20th April 1988
Marital Status:	Married
Permanent Address:	A/P Kalman, Tal-North solapur, Dist.- solapur
Nationality:	Indian
Languages:	English, Hindi, Marathi
Religion cast:	Muslim
Hobbies:	Reading

2. Educational Qualifications

Degree	University	Year	Percentage
S.S.C.	Latur Board	Mar – 2003	**89.66%**
H.S.C.	Pune Board	Feb – 2005	**83.83%**
B.Sc. (Electronics)	Solapur University, Solapur	Apr – 2008	**82.33%**
M.Sc. (Electronics)	Shivaji University, Kolhapur	Apr - 2010	**76.20%**
SET(Electronics Sciences)	University of Pune, Pune	Aug-2010	-------
NET(Electronics Sciences)	UGC-CBSE	Dec-2014	--------

3. Teaching Experience

Employer	Position held	Date of Joining	Date of Leaving	Pay with Scale of pay
Department of Electronics, DKASC, Ichalkaranji. Kolhapur	Jr.Lecturer	19th July 2010	30th Apr 2011	C.H.B
Department of Electronics, DKASC, Ichalkaranji.Kolhaur	Sr.Lecturer	19th July 2010	30th Apr 2011	C.H.B
Department of Electronics (commun. Science), Solapur University, Solapur	Ass. Professor	02nd July 2011	30th Apr 2012	Consolidated
Department of Electronics (commun. Science), Solapur University, Solapur	Ass. Professor	23th July 2012	30th Apr 2013	Consolidated
Department of Electronics (commun. Science), Solapur University, Solapur	Ass. Professor	8th July 2013	1st May 2014	Consolidated
Department of Electronics (commun. Science), Solapur University, Solapur	Ass. Professor	7th July 2014	30th Apr 2015	Consolidated

Educational Project
 # M.Sc Project: Design of RISC controller using Handel-c

 # B.Sc. Project: Quiz buzzer

4. Career summary

- Interest in working with microcontroller based projects.
- Passed SET exam in Electronics Sciences conducted by university of pune on 8 August 2010.
- Passed NET exam in Electronics Sciences conducted by UGC-CBSE on December 2014.

Career Objective

My prime objective is to work for growth & development of organization where my knowledge & skills would be my assets. I have communication and interpersonal skills, good work ethic and the ability to work well in a team or individual environment. My sincere efforts will give my best to organization I join.

5. Member of Professional Bodies

Life member of Society for Promotion of Excellence in Electronics Discipline (SPEED), 2014.

6. AWARDS AND HONOURS

1.	**Certificate of Merit Scholarship** (April 2010) for meritorious performance in the subject of Electronics at M.Sc –I examination, Shivaji University, Kolhapur, Maharashtra, India.
2.	**"Late Shantaram Narayan Waigankar Paritoshik"** for securing highest number of marks in the subject of Electronics at M.Sc examination held in April 2010.
3.	**Best First Paper Presentation Award** "Development of Wireless Sensor Network for Hazardous Gas Leakage Detection", National Conference on Recent Trends in Electronics and Instrumentation-[NCRTEI-2013], Organized by Dept. of Electronics and Instrumentation, BHARTATHIAR UNIVERSITY, COIMBATORE (T.N).
4.	**"Rank Certificate"** :Secured 6th Rank in shivaji university amongst the examination held in April 2010 examination

7. Computer Skills

Languages Known:	C, C++, Embedded c

Software's known:	MPLAB, keil, AVR studio, proteus, ISE project Navigator, MATLAB, CCS,X-CTU,WSN Planner
Extra work	Reading Books

8. Extra Curricular Activities

1.	Acted as a staff member and committee member for smooth conduct of Workshop on "Hands on Training on microcontroller" held in the year 2011-12 by Solapur University, Solapur.
2.	Acted as a staff member and committee member for smooth conduct of on "MATLAB and Simulink" held in the year 2012-13 by Solapur University, Solapur.
3.	Acted as a staff member and committee member for smooth conduct of Workshop on "Latest trends in material characterization techniques" held in the year 2014-15 by Solapur University, Solapur.
5.	Active member of Workshop on "Latest Trends in Fundamental Research" held in the year 2014-15 by Solapur University, Solapur.
6.	Appointed as a moderator in the subject of "Mobile computing" at the M.CA (Solapur university, Solapur) on 11-1-14.
7.	Appointed as a moderator in the subject of "Mobile computing" at the M.Sc Computer Science (Solapur university, Solapur) on 11-1-14.
7.	Delivered a Guest lecture on "Mobile Communication" in V.P Polytechnique College, Indapur on 16-09-2011.
8.	Delivered a Guest lecture on "Basics of 8051 microcontroller" in V.P Polytechnique College, Indapur on 13-02-2012.

9.	One Year teaching experience in Junior and Senior College of DKASC College, Ichalkaranji on 19thJuly 2010 to 30th 2011.
10.	Contributed as a resource person in the one day workshop organized by department of electronics, Sangmeshwar College, Solapur on on 30/01/2015.
11.	Contributed as a resource person in the one day workshop organized by department of electronics, DBF College, Solapur on 08/02/2015.
12.	Co-PI of the project submitted to the DST "Design and Development of wireless sensor network for agriculture: water irrigation management.
13.	Visited KBP Pandharpur, S.S.M Barshi, Dayanand college, Solapur and Sangmeshwar college, Solapur with a moto to explain role of Electronics(Communication Science) in S& T, Job opportunities in industrial sector.

Declaration

I hereby declare that, the particulars mentioned above are correct to the best of my knowledge and belief.

Date:-

Place: - Solapur

Yours faithfully

(Miss.Mujawar T.H)